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Module 1

Solutions



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Chemistry 20

Module 1

Solutions

Chemistry 20
Module 1: Solutions
Student Module Booklet
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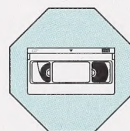
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Welcome to Chemistry 20!

We hope you'll find this course interesting and fun. To make your learning a bit easier, watch the referenced videocassettes whenever you see this icon.

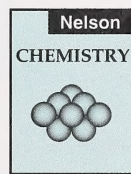


You also have the option of viewing laser videodisc clips when you see the bar codes like this one.



Frame 48350

When you see this icon, study the appropriate pages in your textbook.



Good Luck!

COURSE OVERVIEW

This course contains seven modules. The module you are working in is highlighted in deeper colour.

Module 1 Solutions

Module 2 Acids, Bases, and Gases

*Modules 1 and 2
both deal with
matter that forms
solutions.*

Module 3 Quantitative Relationships

Module 4 Quantitative Analysis

*Modules 3 and 4
both deal with
aspects of
stoichiometry.*

Module 5 Chemical Bonding

Module 6 Organic Compounds

Module 7 Organic Reactions

*Modules 6 and 7
both deal with
organic chemistry.*

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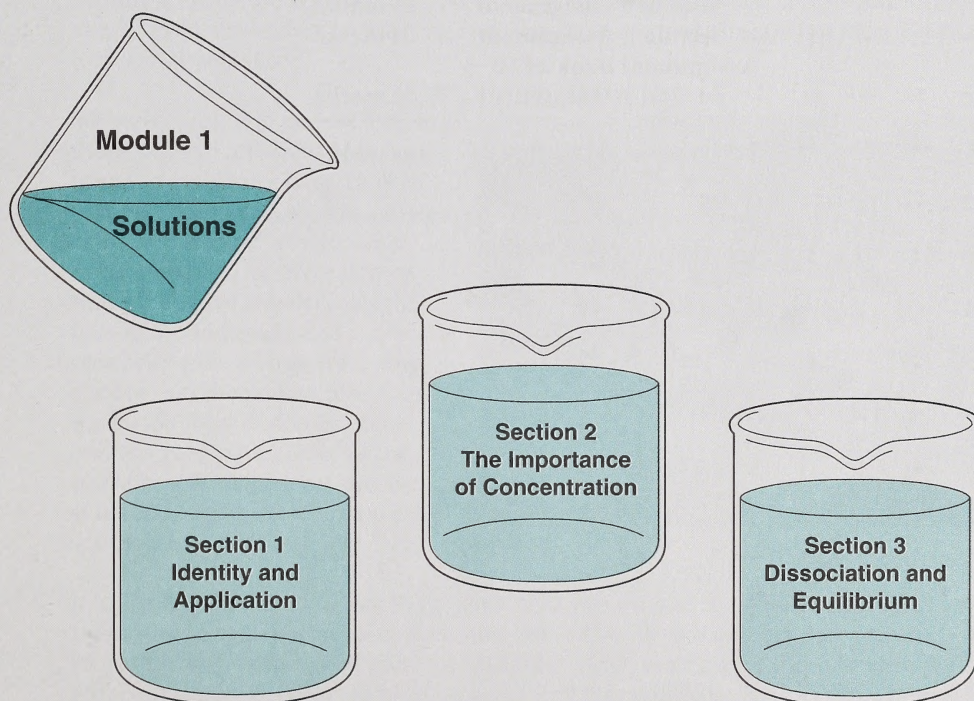
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MODULE OVERVIEW

Have you ever been travelling through the mountains and wished you could stop and have a drink from a mountain stream? Is the water safe to drink?

Your answer to this question is not a simple yes or no. What information might you need to know in order to make a decision? You may need to be aware of what substances have mixed into the stream, the amounts of these substances, and if these amounts will do you any harm. If the substances are harmful, how can they be removed from the water?

In this module, you will be studying about mixtures called solutions. Throughout the module, you will see what these solutions have to do with living things and with modern technology.



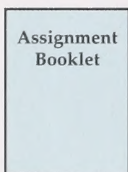
Evaluation

The document you are presently reading is called a Student Module Booklet. It will show you, step by step, what to do and how to do it.

This module, Solutions, has three sections. Within each section, your work is grouped into activities. Within the activities, there are readings and questions for you to answer. By completing these questions you will construct your own learning, discover scientific connections, and apply what you have learned. The suggested answers in the Appendix of this Student Module Booklet will provide you with immediate feedback on your progress.

In this module, you will be directed to the accompanying Assignment Booklets. You are expected to complete two Assignment Booklets for this module. Your grading in this module is based upon the assignments that you submit for evaluation. The mark distribution is as follows:

Assignment Booklet 1A	
Section 1 Assignment	35 marks
Section 2 Assignment	25 marks
Assignment Booklet 1B	
Section 3 Assignment	40 marks
TOTAL	100 marks



When you see this icon, turn to the appropriate Assignment Booklet to find the assignment questions for that section.

Science Skills

Science Skills

- ☒ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

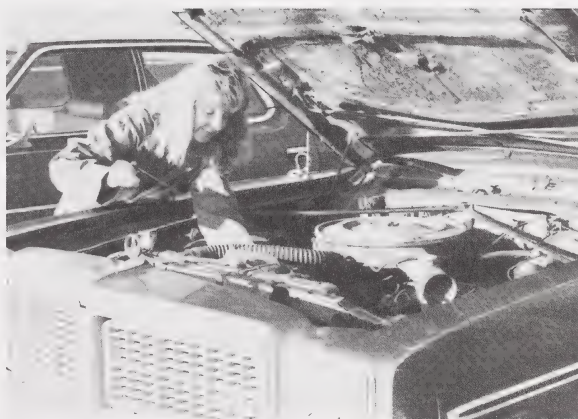
One of the exciting features of this course is that you will develop and improve your ability in the area of science skills. These skills would include

- initiating and planning
- collecting and recording
- organizing and communicating
- analysing
- connecting, synthesizing, and integrating
- evaluating the process or outcomes

Although these skills are referred to as science skills, it is important to remember two key ideas.

First, these skills are not just for science. Any time that you might solve a problem or make a decision, some combination of these skills would be used. Therefore, the skills you will develop in this course will be very useful for life-long learning. Nearly every activity of your life will require you to solve a problem or make a decision. Some people would even argue that, in the long run, the skills are more important than the particular topics that you study.

Secondly, you will be free to use these skills in a variety of ways. It would be wrong to assume that every scientist uses these skills in the same way to solve every problem. Science is very much a human activity, which means individuality and creativity play a large role. The society that the person lives in, the technology that is available, and the very personality of the scientist will determine which skills are combined to create a solution to a problem.



It follows from this idea that the science that you do and the science skills that you prefer to use will be unique to you; and that's OK. It also follows that you likely will not be performing at the same level for all skills, which is a natural thing. In this course you will continually practise all of these skills and you will have an opportunity to assess your level of performance in each skill. These science skills will be developed further in Activity 1 and explained in detail in the Appendix for this module.



NASA

Important Notes

There are no response lines to write on for the questions asked in the student module booklets of this course. This means that you will need to have paper on which to answer the questions handy at all times. It's probably a good idea if you keep your answer pages in a binder or folder so that they do not get lost and they are easier to refer to when reviewing or studying. You will also require graph paper and a calculator. Read all the questions carefully and answer them as completely as possible. Then check your answers in the Appendix. This will allow you to assess your growing abilities in this course.

It is also important that you work through the module activities thoroughly before attempting the questions in the Assignment Booklets. This will help you to achieve a greater degree of success in your studies.

Disposal Information

Any chemicals used in investigations in this course should not be poured down the sink unless stated otherwise. Keep waste materials in closed, labelled containers. Contact your nearest high school or fire department for disposal information.

Identity and Applications



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If you depended on a lake for your drinking water, how could you make sure that the water was safe to drink? If you were to take a sample of the water and look at it closely, you might be able to tell if the water was safe. You might also be able to check its purity by tasting it. However, is this degree of checking enough? Even though the lake water may look and taste good, there may be something dangerous that is dissolved in the water. This substance may not be detected without more exacting tests.

Chemists attempt to describe the exact nature of all the substances in a mixture or solution by using various scientific methods.

In this section, you will be introduced to the methods that will help you develop your science skills. You will see why chemicals are easier to work with when they are in solution form. You will learn how to define a solution and discover how substances dissolve in water. You will learn to design tests for discovering which ions are present in solution, and you will examine some of the technology that deals with solutions.

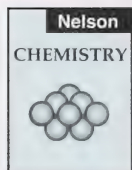
ACTIVITY

1 Your Growth in Science Skills



Has this ever happened to you? You are not concentrating as much as you should and, all of a sudden, oops! Spilled pop on the carpet! Now what are you going to do?

You have probably run into many problems in your life, like spilled pop, where you've had to come up with a solution. Many of your solutions, even though you may not have realized it, probably had a scientific or systematic basis.



In this activity, you will focus on several scientific problem-solving skills in the investigations you examine. The background you develop in science skills that you develop now will help you later in other module activities. For an introduction to science skills and problem solving, read the bottom paragraph of page 17 and the top half of page 18 in your textbook.

Special Note

Remember that whenever you answer questions in this course, your responses will be written on separate paper. Keep some paper handy at all times. Answer all questions carefully.

1. In the progress of scientific problem solving, what steps do scientists go through?
2. How do scientists evaluate the scientific problem solving process?

Check your answers by turning to the Appendix, Section 1: Activity 1.

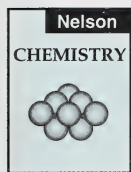
You are still probably wondering how to solve the problem of the spilled pop. The following sample investigation will allow you to solve this problem. You will also familiarize yourself with these concepts:

science skills – processes and their component skills required to obtain a solution to a particular problem

- the problem solving approach used in the investigations you will do in this course
- the science skills you will use in the course

Further information on the problem solving model can be found in Appendix B (page 522) of your textbook.

Investigation 1.1: Stain Removal



Work through the sample investigation on pages 18, 19, and 20 of your textbook.

It is not necessary that you actually perform this investigation, as long as you get a clear understanding of how each step in an investigation should be developed. However, you can certainly perform the investigation if you wish.

Please note the following as you study the investigation:

- the steps of the investigation (problem, prediction, experimental design, etc.) and how these steps are performed
- the safety symbols used
- the method the textbook will use in each investigation to tell you which steps you need to do

Answer the following questions when you have finished.

3. What is the difference between the purpose and the problem of an investigation?
4. Describe the difference between an experimental design and a procedure of an investigation.
5. How does the evidence step differ from the analysis?
6. In the investigation icon found in the textbook margin, how are the steps to be performed indicated?

Check your answers by turning to the Appendix, Section 1: Activity 1.

The following chart illustrates the relationship between the investigation steps and science skills. You may recall that the science skills were discussed briefly in the introductory pages of this module. They are described more fully in the module Appendix.

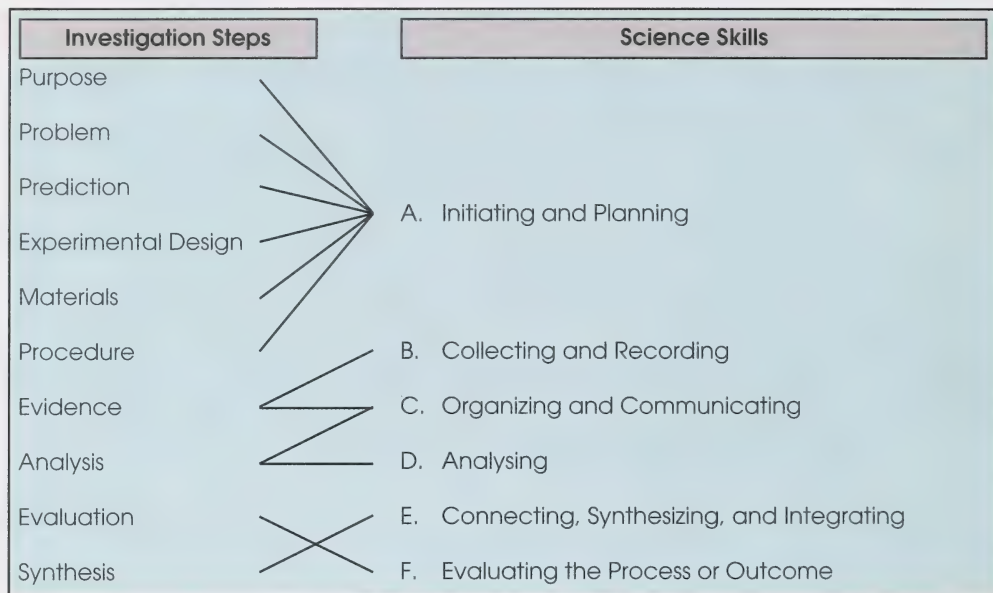


FIGURE 1.1: The Science Process

Figure 1.1 will be very valuable to you in the understanding of what is involved in each science skill you will be using.

As you complete this course you will be continually practising the skills of science. You will be asked to assess your ability and you will receive feedback on your progress. The whole purpose of this process is so that you can improve and grow in your abilities.

In order to inform you of suitable opportunities to assess your skills, a science skills icon will be used in the margin throughout the modules. The specific skills being practised will be indicated by checkmarks.



Full Science Skills Titles

Science Skills	
☒ A. Initiating	Initiating and Planning
☒ B. Collecting	Collecting and Recording
☒ C. Organizing	Organizing and Communicating
☒ D. Analysing	Analysing
☐ E. Synthesizing	Connecting, Synthesizing, and Integrating
☐ F. Evaluating	Evaluating the Process or Outcome

Besides doing your own assessment of your science skills, a teacher will also assess your science skills.

The method used to assess your ability in each of these skills involves using a **level** of performance. There are five possible levels. Level 5 is the top level of performance. It describes work that would be done of a college or university calibre. Since you are still a high school student it is reasonable to assume that you will likely be operating at levels 2, 3, or 4 in most of the skills. Note that it is natural to be performing at different levels for different science skills.



To familiarize yourself with the differences between each of these levels, read the descriptions for each level as they are applied to each of the six science skills. The descriptions can be found in the beginning of the Appendix to this module.

To gain practice in assessing levels in science skills, perform the following investigation.

Investigation: Aluminum in Copper(II) Chloride

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Whenever you do an investigation or other aspects of this course involving science skills, examine the science skills icon in the margin.

In this investigation, the icon indicates that you will be concentrating on the skills of collecting and recording (B. Collecting), organizing and communicating (C. Organizing), and analysing (D. Analysing).

Carefully follow the directions given for this investigation. Pay special attention to the required components, safety aspects, and applied science skills.

qualitative – observations of what is present, made without measurements

quantitative – observations of what is present, made with measurements

The purpose of this investigation is to make **qualitative** and **quantitative** observations when a piece of aluminum foil is mixed into a solution of copper(II) chloride.

Materials

- aluminum foil
- copper(II) chloride
- distilled water
- 250 mL beaker
- stirring rod
- thermometer

Procedure

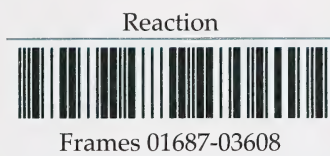
Note: Wear goggles during this investigation.

- Cut a 10 cm × 10 cm piece of aluminum foil.
- Measure about 5 g (5 mL or 1 tsp.) of copper(II) chloride, CuCl_2 .
- Pour about 100 mL of distilled water into a 250 mL beaker.
- Slowly and carefully add the copper(II) chloride to the water without stirring. Observe.
- Dissolve the copper(II) chloride in the water by stirring. The thermometer can be used to stir the solution if you are careful. Observe.
- Crumple the piece of aluminum foil into a loose ball (about 2 cm diameter).
- Place the aluminum foil into the $\text{CuCl}_{2(aq)}$ solution.
- Push the aluminum ball down into the solution with the thermometer, noting observations and temperature readings.
- Dispose of solid waste in the garbage. Liquid waste can be poured down the sink.

Caution

7. Complete the evidence for the investigation by recording your observations on a separate sheet of paper. Your observations will be more organized if placed in a table.

If you have access to the laser videodisc *The Chemistry Disc: Exothermic and Endothermic Reactions*, view the sequence that starts with frame 01687. This gives you another example of the reaction in the investigation.



If your laser videodisc player does not have a bar code reader, use the frame numbers provided with the bar code icon to search for and then play each sequence.

Analysis

Complete the analysis for the investigation by doing the following questions.

8. Based on your observations, was this reaction exothermic (heat released) or endothermic (heat absorbed)? Explain how you know.
9. What was the orange-red solid on the surface of the aluminum foil?
10. Identify two pieces of evidence that a chemical change occurred.

Check your answers by turning to the Appendix, Section 1: Activity 1.

11. Based on the skills information given in the Appendix, and your own assessment abilities, write your assessment for each of the following sample evidence tables. Assess both collecting and recording (B.), as well as organizing and communicating (C.) skills.

EXAMPLE EVIDENCE TABLE 1

Substance	Observations
aluminum foil	The silver solid turned red when put into the beaker. Rust was formed.
copper chloride solution	The blue solution bubbled when the foil was put in.

Example Table 1: B. Collecting – level ☐

C. Organizing – level ☐

EXAMPLE EVIDENCE TABLE 2

Substance	Observations
aluminum foil	Before the reaction the 10 cm × 10 cm foil was silvery in colour.
copper(II) chloride	Before the reaction the copper(II) chloride was a blue solid weighing 5 g.
water	The water was a clear liquid before the reaction.
aluminum foil in solution	The aluminum foil started to smoke when it was placed in the solution. A reddish-brown solid appeared on the foil's surface.
copper(II) chloride solution	When the foil was added, the solution started to bubble around the edges of the foil and steam rose up.

Example Table 2: B. Collecting – level ☐C. Organizing – level ☐**EXAMPLE EVIDENCE TABLE 3**

Before placing the aluminum foil into the solution:

Substance	Observations	
	Quantitative	Qualitative
aluminum foil	10 cm × 10 cm 0.5 g	silvery solid, shiny in appearance
copper(II) chloride	5 g (5 mL or 1 tsp.)	blue granular solid, dull appearance; when placed in water – initially was green but when dissolved, turned blue
water	23.5°C 100 mL	clear, colourless liquid

After placing the aluminum foil into the solution:

Substance	Observations
aluminum foil	10 s – aluminum foil appeared to be releasing steam when mixed in the $\text{CuCl}_{2(aq)}$ 20 s – small patches of reddish-orange solid appeared on the surface – some small patches of black solid 50 s – surface of foil almost entirely covered with red solid – still a few patches of black and silver colour
copper(II) chloride solution	10 s – some steam starting to appear to rise from solution; some bubbles 20 s – more bubbling of solution around edges of foil; temperature has risen to 25.5°C 250 s – fairly vigorous bubbling around the edges of foil; solution has increased to 41.8°C

Example Table 2: B. Collecting – level ☐C. Organizing – level ☐

Check your answers by turning to the Appendix, Section 1: Activity 1.

If the previous investigation had been one of your assignment questions, the level of your performance in the three science skill categories that were focussed on would be assessed. Both you and a teacher would assess the response level.

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

The question would have a science skills icon like the one shown in the margin. The skills to be evaluated would be checked.

Then once you completed your answer for the question, you would reproduce a science skills assessment box. This is where you and your teacher would each write evaluations of your skill level for each identified science skill. The box would look like the following:

Self: A.	B.	C.	D.	E.	F.
Teacher: A.	B.	C.	D.	E.	F.

As an example, you may have thought that your skill level in the skills indicated by boxes B, C, and D were as follows for the previous investigation. You reproduce a box similar to the following at the end of your response to the assessed question.

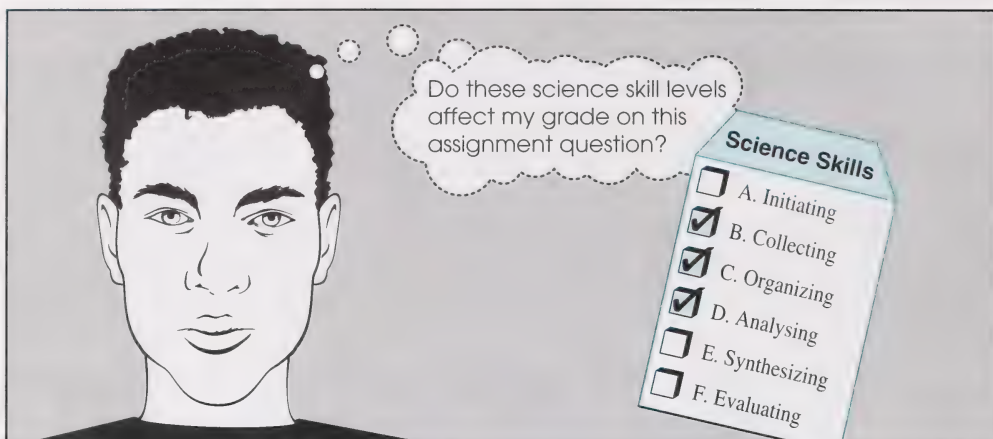
Self: A.	B. 4	C. 4	D. 3	E.	F.
Teacher: A.	B.	C.	D.	E.	F.

You then handed in the completed response page to be marked. When the assignment was returned, the teacher had assessed your skill level of performance as shown:

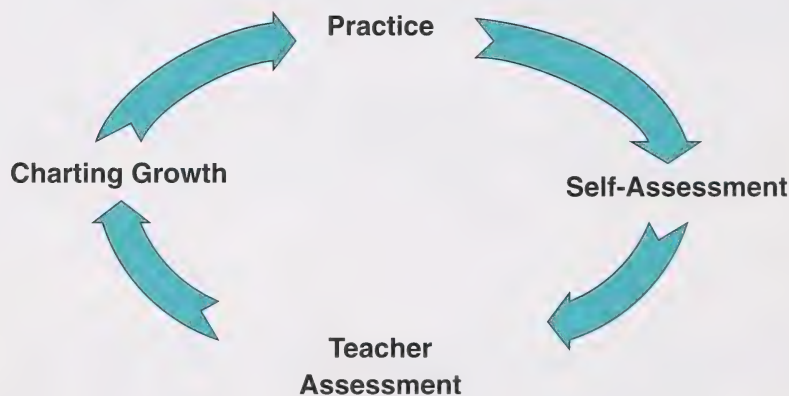
Self: A.	B. 4	C. 4	D. 3	E.	F.
Teacher: A.	B. 3	C. 4	D. 3	E.	F.

The teacher assessed your science skills in collecting and recording data one level lower than you did, but the other two skills were assessed the same. What does this mean? It means that the teacher probably thought you could have been more complete in your observations than you thought.

It is important for you to realize that this teacher skill level assessment should NOT be interpreted as part of your grade. Rather, it is valuable feedback to help you to know the areas where you need to improve.



Everyone can improve their science skill abilities. Therefore, to help you improve and grow in your abilities with these skills, a strategy has been developed for this course.



12. a. Where will you practise improving your skills?
- b. When will you know it is time to practise using your science skills?
- c. How will you know what skills you are practising?
13. How will you know when your science skills are being assessed in the assignment questions?
14. Will the level assessment of your skills affect your grade on the particular assignment question?

Check your answers by turning to the Appendix, Section 1: Activity 1.

The whole purpose of identifying skills with the margin icons is to increase your awareness of, and growth in, each of the science skill categories. As seen in the previous example, your self-assessment may be the same, or different, than your teacher's assessment in these science skills. The important thing is that you gain practice and are able to improve in the skills themselves and in your ability to assess your own skill level.



Feedback from the assessment (both self and teacher) of your science skills is valuable and needs to be charted over time. As you progress through the course you will be practising the same skills throughout each module. To keep track of your progress and growth, you will record your self-assessment and teacher assessment on a spreadsheet located in the appendix of this module. This allows you easy reference to the skills level information charts. This sheet is to be photocopied or reproduced and is to be handed in with the last assignment of the course (in Module 7). You may wish to make a copy of the spreadsheet at this time and keep it posted for handy reference, or you may keep a copy at the start of your science notebook.

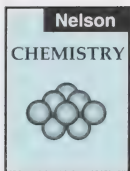
15. Where do you find more information on the science skills and levels?
16. What is the purpose of keeping track of your level of skill performance?
17. Turn to the Appendix and find the spreadsheet for recording the assessment of process skills.
 - a. When your assignments are returned, what two assessments do you record on the spreadsheet?
 - b. What is the advantage of recording **all** the assessments, from the whole course, on one spreadsheet?

Check your answers by turning to the Appendix, Section 1: Activity 1.

As mentioned at the beginning of this activity, the science skills you develop and improve upon now will not only benefit you in your further science studies. These skills will be with you for any problems you tackle in life, in general.

ACTIVITY

2 What Are Solutions?



Do you remember what a pure substance is? What is a **compound**? In Science 10, you studied the classification of matter. To review how matter is classified, read page 113 in *Nelson Chemistry*.

In this section, you will be focussing on **homogeneous mixtures** called solutions. This kind of mixture is uniform throughout. You cannot see the separate components of the mixture even though there may be a way that you could separate them.

compound – a pure substance composed of a combination of two or more atoms

homogeneous mixture – two or more components dissolved to form a uniform substance

element – a pure substance composed of only one kind of atom

heterogeneous mixture – a mixture that has two or more parts that can be distinguished from one another

- Using Figure 5.1 on page 113 of your textbook, classify the following examples of matter. If the substance is pure, then state whether it is an **element** or a compound. If the substance is a mixture, state whether it is homogeneous or **heterogeneous**.

a. a silver earring	e. gasoline
b. ice	f. table sugar
c. concrete	g. pop
d. raisin cookie	h. vinegar

Check your answers by turning to the Appendix, Section 1: Activity 2.

Solutions are made up of two or more components. Each component is determined on the basis of how much of the substance is present. The following figure illustrates the solute and solvent components that make up a homogeneous mixture.

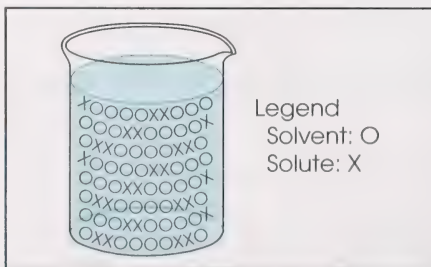


FIGURE 1.2: A Model of a Homogeneous Mixture

As shown in Figure 1.2, the solvent is the component of the mixture that is present in the greater quantity. The solute is the component that is present in the smaller quantity. There can be more than one solute but only one solvent in a solution. Solutes and solvents can be solids, liquids, or gases.

2. In the following table classify each of the components of the four solutions as either a **solute** or a **solvent**.

Solution	Component	Amount	Solute or Solvent?
Tooth Filling	mercury	50%	
	silver	35%	
	tin	15%	
Air	argon	0.93%	
	carbon dioxide	0.03%	
	oxygen	20.9%	
	nitrogen	78.1%	
	others	0.04%	
Steel	aluminum	1%	
	nickel	14%	
	iron	58%	
	manganese	13%	
	chromium	14%	
Sea Water	chloride	1.898%	
	sodium ions	1.056%	
	magnesium ions	0.127%	
	sulphide	0.088%	
	calcium ions	0.040%	
	potassium ions	0.038%	
	bromide	0.065%	
	water	96.684%	
	others	0.004%	

FIGURE 1.3: Solutions and Their Components

Check your answers by turning to the Appendix, Section 1: Activity 2.

solute – the substance present in a lesser amount

solvent – the substance present in the greatest amount

alloy – a uniform mixture of metals

There are some specific kinds of solutions. For instance, an **alloy** is a solution made up of metals.

To learn more about the variety of solutions, use Figure 1.3 to answer the following questions.

3. The alloys are _____ and _____.
4. The solution that is made up of solids and liquids is _____.
5. The solution that is made up of gases is _____.
6. Is water the solvent in all solutions?
7. Is the solute a solid in all solutions?
8. Is the solute in a different **state** than the solvent in the sample solutions?

state – the phase of the substance

Check your answers by turning to the Appendix, Section 1: Activity 2.

From working with the table Solutions and Their Components, you probably noticed the amounts of solutes found in the different solutions. One method of describing the amount of solute is the **concentration**. A **concentrated solution** has a greater amount of solute in a given volume than a **dilute solution**. You can think of it as how crowded the particles are in the mixture.

concentration – the amount of solute in a certain volume of solution

concentrated solution – a term referring to a relatively large amount of dissolved solute

dilute solution – a term referring to a relatively small amount of dissolved solute

9. Identify the concentrated and the dilute solution in Figure 1.4.

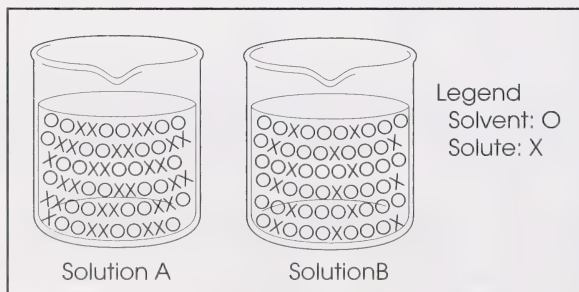


FIGURE 1.4: Solutions to Compare

So that you can practise further with the concept of concentrated versus dilute solutions, look back to Figure 1.3 and answer the next three questions.

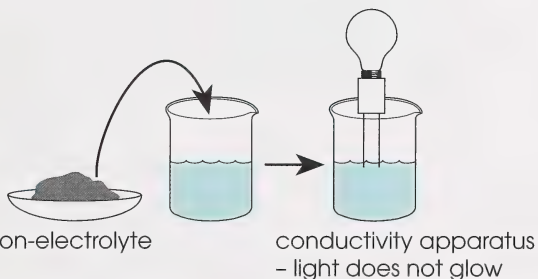
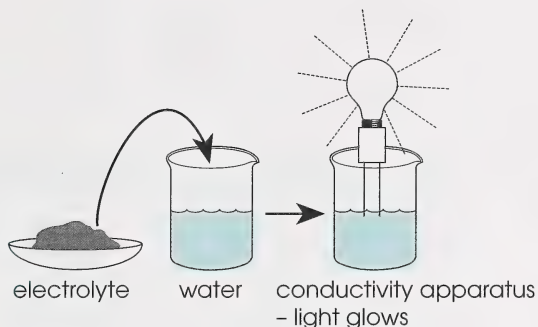
10. The most concentrated solute in the tooth filling is _____.
11. In air, which of the component gases has the lowest concentration?
12. In sea water, which solute has the second highest concentration?

Check your answers by turning to the Appendix, Section 1: Activity 2.

aqueous – dissolved in water

electrolyte – a solute which causes a solution to conduct electricity

non-electrolyte – a solute that dissolves to create a non-conducting solution



As you have learned, solutions can be gaseous, liquid, or solid in nature. However, the most common solutions, and the ones you will be focussing on in this module, are **aqueous** solutions. These are solutions that have water as the solvent. The solute that dissolves in water can be classified as an **electrolyte** or a **non-electrolyte**. When an aqueous solution is tested with a conductivity apparatus, the type of solute present can be identified.

The following investigation will give you practice in identifying the type of solute dissolved in a solution.

Investigation: The Conductivity of Solutions

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Carefully follow the directions given for this investigation. Pay special attention to the required components, safety aspects, and applied science skills.

The purpose of this investigation is to classify solutes as electrolytes or non-electrolytes.

Materials

- about 0.10 g (1 mL or 1/4 tsp.) table salt
- about 0.10 g (1 mL or 1/4 tsp.) white table sugar
- 15.0 mL of 0.10 mol/L hydrochloric acid
- 60.0 mL distilled water
- conductivity apparatus
- test tubes
- stirring rods
- scoopula

Procedure

- Test the distilled water, table salt, and table sugar with the conductivity apparatus.
- Make two solutions by completely dissolving the table salt and table sugar in 5.00 mL samples of distilled water.
- Test the salt solution, sugar solution, and the hydrochloric acid with the conductivity apparatus.

As you work through the procedure, answer questions 13 to 16.

13. Record the degree of conductivity of the six substances in a data table. You could describe the degree of conductivity as

- does not conduct
- low conductivity
- high conductivity

Substance	Degree of Conductivity
Distilled water	
Table salt	
Table sugar	
Salt solution	
Sugar solution	
Hydrochloric acid	

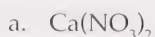
14. Why was the conductivity of the water tested?
15. Which solution is the best conductor of electricity?
16. Classify the three pure substances as **ionic** or molecular.

ionic – a substance composed of positive and negative ions

Check your answers by turning to the Appendix, Section 1: Activity 2.

The preceding investigation was designed so that you could see what class of solutes produced solutions that conducted electricity. Answer the questions which follow based upon the data from the investigation.

17. What type of solutes are electrolytes?
18. What type of solutes are non-electrolytes?
19. What type of particle is formed when ionic compounds dissolve?
20. What type of particle allows a solution to carry a current of electricity?
21. Classify the following solutes as electrolytes or non-electrolytes.



Check your answers by turning to the Appendix, Section 1: Activity 2.

Solutions are homogeneous mixtures of a solute and solvent. If a solute is ionic or an acid, it will conduct. If the solute is molecular, it will not conduct.

There are many examples of common everyday solutions around you. Can you think of any?

ACTIVITY

3

Solutions and Systems

What common molecular substance covers over two-thirds of the Earth's surface? It is water, and the effect it has on your life and the lives of other living creatures in the biosphere is staggering. Aqueous solutions of all kinds surround you.

systems –
integrated
components
working together

There are examples of aqueous solutions in living organisms and in non-living **systems**. Many of these aqueous solutions contain ionic solutes. To see where the ionic solutes come from on this planet, look at the following figure.

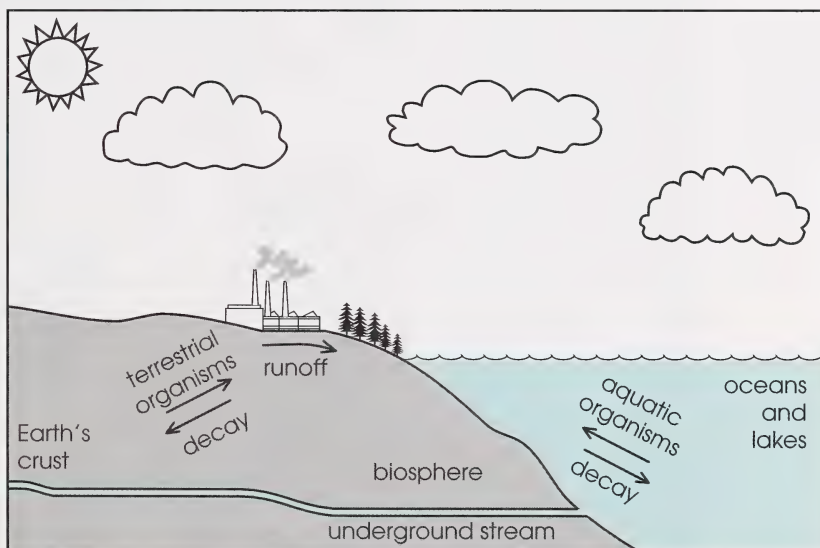


FIGURE 1.5: The Dissolved Mineral Cycle

minerals –
relatively pure
metal
compounds

Figure 1.5 shows that dissolved solids such as **minerals** enter the lakes and oceans by travelling through rivers and underground streams. Organisms use these electrolytes for their life processes and then the electrolytes return to the environment after organisms have died and decayed.

- Use Figure 1.5 to answer these questions.
 - What do the arrows represent?
 - What part of the Earth is not really involved in the cycle?
 - According to the diagram, is the amount of dissolved mineral constant or variable? Explain.
- Name some sources of solutes that may enter the biosphere and are not naturally occurring.

The cycle of dissolved minerals shows how closely connected the living and non-living world is. Your body contains an aqueous solution that acts as a transportation system for cells. **Plasma**, the liquid part of blood, is an example of a solution found in living organisms.

plasma – the liquid portion of blood that remains after the cells have been removed

- In the table of plasma components that follows, classify each component as either an electrolyte or non-electrolyte.

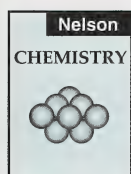
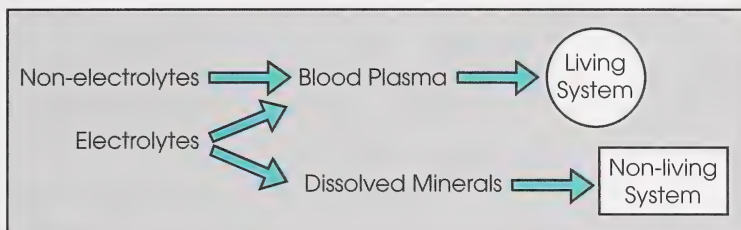
Name	Formula	Electrolyte or Non-electrolyte
Biocarbonate ions	$\text{HCO}_3^-_{(\text{aq})}$	
Calcium ions	$\text{Ca}^{2+}_{(\text{aq})}$	
Chloride ions	$\text{Cl}^-_{(\text{aq})}$	
Fatty acids		
Glucose	$\text{C}_6\text{H}_{12}\text{O}_{6(\text{aq})}$	
Glycerol	$\text{C}_3\text{H}_5(\text{OH})_{3(\text{aq})}$	
Oxygen	$\text{O}_{2(\text{aq})}$	
Potassium ions	$\text{K}^+_{(\text{aq})}$	
Proteins		
Sodium ions	$\text{Na}^+_{(\text{aq})}$	
Sulphate ions	$\text{SO}_4^{2-}_{(\text{aq})}$	
Urea	$\text{CO}(\text{NH}_2)_{2(\text{aq})}$	

Check your answers by turning to the Appendix, Section 1: Activity 3.

You have just looked at examples of how solutions are important to two kinds of systems. The dissolved mineral cycle represents a non-living system. The other example, blood plasma, represents solutions in a living system.

Both of these solutions contain a variety of solutes, some of which are electrolytes. How do the substances **dissolve** in the solution and why do the solutions conduct electricity?

dissolve – mix two or more substances to form a solution



To further understand how solutes dissolve, read pages 115 to 117 in *Nelson Chemistry* and then answer the following questions.

4. According to **Arrhenius**, what happens to molecular compounds when they dissolve?
5. Explain what happens to an ionic compound when it dissolves in water.
6. What do the water molecules do when a solute dissolves?

Arrhenius – scientist who proposed a theory to explain why some solutions conduct electricity

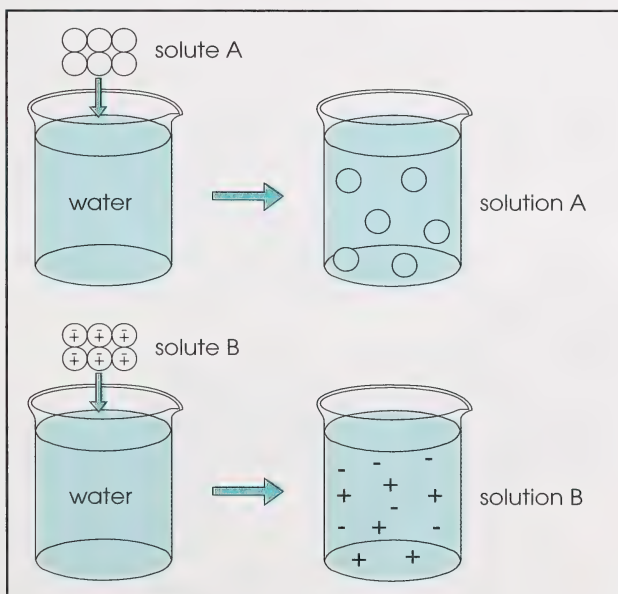


Figure 1.6 illustrates models showing solutes A and B forming solutions A and B. Use the models to answer the following question.

FIGURE 1.6: Models of Dissolving

7. a. Solute _____ will create the greatest number of particles.
 b. Solution _____ has the greatest concentration.
 c. Solute _____ has **dissociated**
 d. Solute _____ has dissolved but not dissociated.
 e. Solution _____ would conduct electricity.
8. Define ionization.
9. Do pure acids contain **ions** or do they exist as molecules?
10. According to Arrhenius, what do acids do when they dissolve?
11. What is the difference between ionization and dissociation?

dissociated – separated into positive and negative ions when an ionic compound is dissolved

ions – particles formed from atoms or molecules that have a charge

Check your answers by turning to the Appendix, Section 1: Activity 3.

Solutions exist in living organisms or in non-living materials. You have learned a theory proposed by Arrhenius that explains how substances dissolve and form either conducting or non-conducting solutions. How can you apply such theories?

ACTIVITY

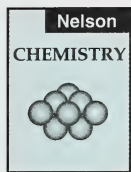
4

Solutions and Technology



The preceding cartoon shows how two people can come up with different ways to solve a problem. Each has a way in mind to remove the old wax from a floor by using ammonia. The person on the left is using ammonia gas; the person on the right is using an ammonia solution. Which method would be the best one?

1. Pick one of the methods presented. Explain why it is the better choice of the two.



Solutions serve many purposes at home and in industry. Read the top half of page 121 in the textbook (don't forget the margin information) to discover the major reasons for using solutions, then answer the questions which follow.

2. List three reasons why solution systems are used instead of pure substances.
3. How does the surface area of a solid reactant compare to the surface area of a solution system?
4. Why is headache medication usually packaged as a tablet to be taken with water?
5. List a solid that you may have in your home that is used when it is dissolved in water.

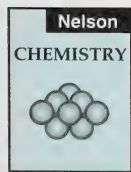
Check your answers by turning to the Appendix, Section 1: Activity 4.

One of the major reasons why solutions are used instead of pure substances is that solutions are easy to handle and control. Solutions can be easily manipulated to increase production of a compound or to control how fast a product forms. Often, advances in technology are arrived at by trial and error processes. The following investigation involves a reaction that can be controlled by manipulating the concentration, temperature, or volume of the reacting solutions. By doing this investigation, you are simulating how a problem in technology could be solved.

Investigation 5.2: The Iodine Clock Reaction

PATHWAYS

If you have access to laboratory facilities, do Part A.
If you do not have access to laboratory facilities, do Part B.



Part A

Carefully read the information given for Investigation 5.2 on page 121 of *Nelson Chemistry*. Pay special attention to the required components, safety aspects, and applied science skills.

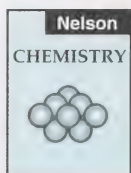
Guidelines

Science Skills

- ☒ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

- Use a maximum of 5.00 mL of Solutions A and B for each trial.
- Begin timing the reaction as soon as the two solutions are combined.
- You can use water baths to adjust the temperature of the reactants. Do not heat the solutions above 50°C.
- Before you write an experimental design, do the following step so that you will have an idea of how the reaction works.

Pour 2.0 mL of Solution A into a test tube containing 2.0 mL of Solution B. Mix the solution by transferring the mixture back and forth between the two test tubes. Note the time required for the reaction to happen.



- On separate paper, write your design, materials, procedure, and evidence as outlined in the following questions. If you are uncertain about any of these concepts, refer to pages 18 and 19 of your textbook.
6. Write a general description of your design.
 7. Make a list of your required materials.
 8. List the steps in your procedure.
 9. Prepare a data table to record your evidence.

Check your answers by turning to the Appendix, Section 1: Activity 4.

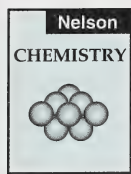
If your design is similar to any of the three listed in the Appendix, you may proceed with the investigation. If not, you may use one of the procedures listed or adjust yours to make it suitable.

10. Write an analysis of the evidence you collected.

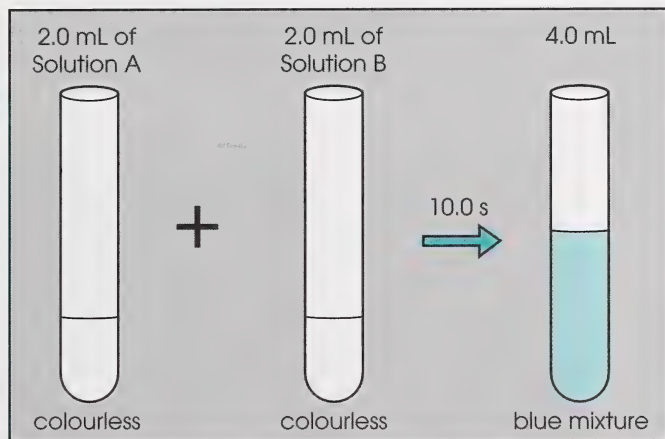
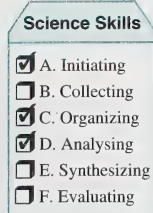
Check your answers by turning to the Appendix, Section 1: Activity 4.

End of Part A

Part B



Carefully read the information given for Investigation 5.2 on page 121 of *Nelson Chemistry*. Pay special attention to the required components, safety aspects, and applied science skills.



Before you design an experiment, you need to know how the iodine clock reaction works. Start with two colourless solutions, Solution A and Solution B. The solutions are then mixed in equal volumes. When the initial temperature of the both solutions is 20°C, the mixture turns a dark blue after 10.0 s.

The iodine clock reaction is very reliable as a timed reaction.

11. Write a general description of your design.
12. Make a list of your required materials.
13. List the steps in your procedure.

Check your answers by turning to the Appendix, Section 1: Activity 4.

Does your experimental design look similar to any of the ones listed in the Appendix? If it does then you were successful in preparing to do the investigation.

14. In order that you can do the analysis, check the module Appendix for the answers to question 9, Section 1, Activity 4. Copy one of the given example data tables onto a separate sheet of paper.
15. Write an analysis of the evidence you collected.

Check your answers by turning to the Appendix, Section 1: Activity 4.

End of Part B

qualitative analysis – using diagnostic tests to find out what substances are present

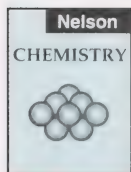
By doing Investigation 5.2, you may have chosen to change the amount of either Solution A or Solution B or to adjust the temperature of the reactants. You could control the rate of this reaction even though you had no idea of what solutes Solution A and Solution B had in them. If you needed to discover what types of solutes were present, you could test the solutions to see if they contained electrolytes or non-electrolytes. This is a **qualitative** test that tells you what type of solute is present.

In the next part of this activity, you will learn about two more qualitative tests for solutions that are based on colours of ions. A qualitative test determines what is present, not how much there is. These diagnostic tests will enable you to identify some specific ions in a solution.

When you watch fireworks, do you know what causes the different colours that you see? Colours can be used to identify types of ions, like the ions present in explosives, but it does not tell you the amount of ions present.



COREL CORPORATION



To learn how to identify ions based on qualitative tests of colour, read page 123 of your textbook. Then use the information tables inside the back cover of your textbook to answer the following questions.

16. Complete questions 8 and 9 from page 123 of your textbook.
17. Review the experiment on qualitative analysis by colour in Lab Exercise 5C on page 123 of your textbook. Write an analysis for the lab exercise.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Check your answers by turning to the Appendix, Section 1: Activity 4.

flame test – a diagnostic tool which identifies the ions present in solution by the colour of flame they produce



Frames 22641-23224

If you have access to the laser videodisc *Chemistry at Work*, find and view the sequence that starts with frame 22641, side B. This will enhance your understanding of **flame tests** and colours of ions.

In this activity, you have learned some reasons for using solution systems rather than pure substances as reactants. You have used some methods to control reactions and you discovered how to identify certain ions by their colours in solution or from data from flame tests.

The methods described in this activity are often used in research and industrial labs for the same purposes of controlling reactions and identifying substances.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

1. Use this list of terms to fill in the blanks in the paragraph that follows.

- | | |
|----------------|-------------------|
| • solute | • non-electrolyte |
| • acid | • solute |
| • concentrated | • solvent |
| • homogeneous | • water |
| • aqueous | • ionic |

This module examines a specific kind of _____ mixture called a solution. A solution is made up of two basic parts, a _____ and a solvent. When you look at a solution, it is impossible to see the solute separately from the solvent because they are mixed together thoroughly. There is less _____ than _____ and they are mixed together evenly. If a solution is _____, then it contains more solute when compared to another solution of the same kind. In an _____ solution, the solvent is _____ and the solute could be an ionic compound, a molecular compound, or a dissolved acid. If the dissolved solute was a molecular compound, then it is classified as a _____ since it does not conduct electricity. If the solute is an _____ compound or an _____ then it is classified as an electrolyte.

The following table gives an explanation of several properties of various types of solutes.

Solute	Dissolves	Dissociates	Ionizes	Ions Form	Conducts
Molecular	✓				
Ionic	✓	✓		✓	✓
Acid	✓		✓	✓	✓

2. Complete the following table of solutions. Vinegar is done as an example.

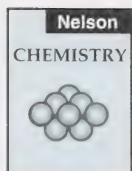
Solution	Vinegar	Salted water	Gasoline	Lemon juice	Beer
Solute	acetic acid	sodium chloride	molecular liquids	citric acid	ethanol
Solvent	water	water	octane		
Dissolves	✓				
Dissociates	no				
Ionizes	✓				
Ions present	✓				
Conducts	✓				

3. Give an example of a solution that is part of a living system and a solution that is part of a non-living system.
4. List three reasons why aqueous hydrogen chloride (hydrochloric acid) is used more often by chemists than $\text{HCl}_{(g)}$.

The electrolytes of a solution can be identified using a flame test, the colour of the solution, or a combination of the two.

5. Use the tables inside the back cover of your textbook to complete the following table.

Solution	Colour Produced by Flame Test	Colour of Solution	Possible Identity of Ion Present
1	yellow	colourless	
2	green	colourless	
3	green	blue	
4	yellow	orange	



Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Do any **one** of the following.

1. Research how the composition of fireworks affects the colour produced. Is there a limit to the colours you can produce? Are some colours more expensive than others?
2. Find out the exact nature of your drinking water. You may telephone, write, or visit the nearest water treatment plant or find this information in your family records. Compare these components to the contents listed on bottled water.
3. Find a container of liquid fertilizer or insecticide in your home. How much information is listed on the container about the contents? Is this clear, precise, and useful?

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

In this section, you have learned about solution systems and their components. You can design tests to determine what kind of solute is dissolved in an aqueous solution. By using diagnostic tests such as conductivity, colour of solution, or a flame test, you can narrow down the specific ions that are dissolved.

In the next section, you will learn how to measure the amount of solute in a solution.

Assignment
Booklet

ASSIGNMENT

Turn to Assignment Booklet 1A and do the assignment for Section 1.

The Importance of Concentration



During the summer, do you ever come inside after spending the morning out in the sun and look in the fridge for something to drink? You're very thirsty so you decide to make a pitcher of lemonade. You add two trays of ice cubes, pour a glass, and enjoy your drink.

Mixing lemonade from scratch is like making an aqueous solution in the lab. You can make a solution if you know the amount of solute to dissolve in the water. When you taste the lemonade, you can judge if the drink has been made properly. How can you ensure that your aqueous solution is made correctly?

In this section, you will learn how to describe the amount of solute dissolved in an aqueous solution and how to make a solution. You will discover how these descriptions and methods may determine the effects some substances have on people and the environment.

ACTIVITY

1

Calculating Concentration

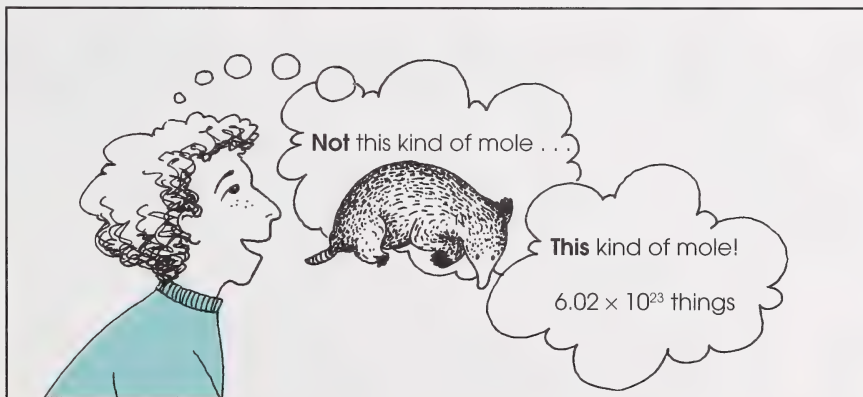
The concentration of a dissolved solute can be described in two main ways: qualitatively and quantitatively. If you say that one soft drink is sweeter than another, you are describing the concentration of the sugar qualitatively. If you specifically said how much sugar was dissolved in each solution, then the description is quantitative.

The qualitative descriptions that you have learned about so far deal with the colour of the solution. To see how colour and concentration are related read page 124 in your textbook up to the section on Concentration-Quantity Calculations. Then answer the following questions.

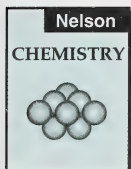
1. According to Figure 5.10 on page 124, what does a dark colour of solution mean compared to a light colour of solution?
2. What is molar concentration?

As you learn from the reading, there are many different ways to express the concentration of a solute quantitatively. In this activity, you will calculate molar concentration.

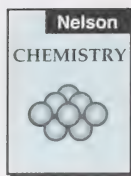
Do you remember from Science 10 what a mole is?



The molar concentration of a solution refers to the number of particles of solute, expressed in moles, in the solution. As you probably remember, it is necessary to deal with such a large number of particles, as represented by the mole unit, because the particles are usually so small.



The molar concentration of a solution can be calculated by several methods. Your textbook uses a method of calculation which is based on the units of the values and conversion factors. Conversion factors are ratios that can be used to convert one unit to another.



The method of calculation is often called the Factor Label Method. To see how this method of calculation works, read the short section on Concentration-Quantity Calculations at the bottom of page 124 of your textbook. Then look at the third example problem on page 125 of your textbook (the ammonia solution example) to see how this calculation is performed. Note in the example that when the terms are arranged properly, the units that are not wanted cancel out.

3. Answer these questions which are based on the example ammonia problem.
 - a. What was the purpose of the conversion factor, 1L / 1000 mL?
 - b. What does the first *m* in *mmol* stand for?
 - c. What determines when the units of terms can be cancelled?

Check your answers by turning to the Appendix, Section 2: Activity 1.

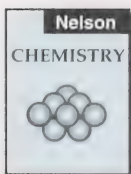
Another example of a calculation involving concentration is illustrated as follows.

Question: What volume (mL) of a solution would contain 0.275 mol of copper(II) sulphate if the concentration of the copper(II) sulphate solution is 0.350 mol/L?

$$\text{Solution: } V_{\text{CuSO}_4} = 0.275 \cancel{\text{mol}} \times \frac{1\cancel{\text{L}}}{0.350 \cancel{\text{mol}}} \times \frac{1000 \text{ mL}}{1\cancel{\text{L}}} = 786 \text{ mL}$$

Note:

- The concentration term is inverted so that the units properly cancel. This automatically tells you to divide by the concentration value.
- The answer is rounded to three significant digits because of the significant digits in the terms. For more information on significant digits and calculations, refer to Appendix E on page 543 of your textbook.



The molar concentration of a solution can also be calculated using a simple formula relationship. Look at the notes given in the right margin of page 125 of your textbook and answer the questions which follow.

4. What is the relationship used in solution calculations?

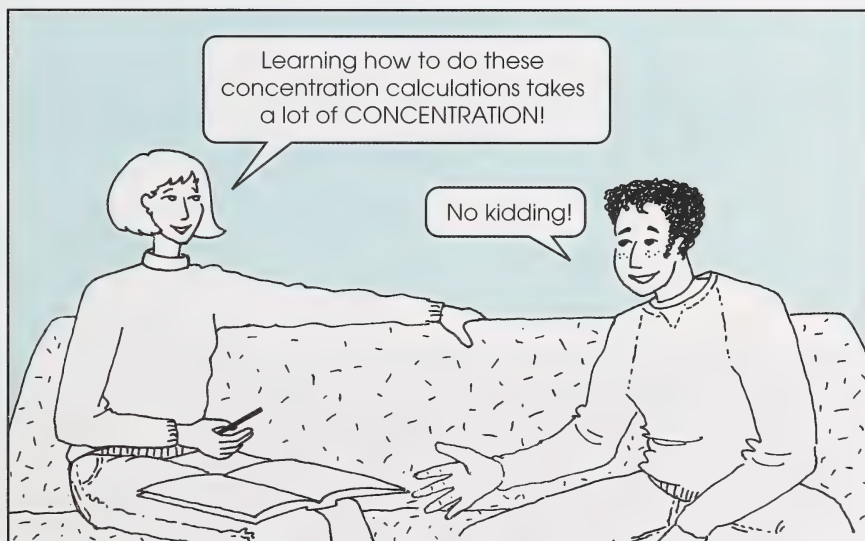
5. Complete a chart describing the variables in the concentration relationship.

Symbol	Description	Units
C		
n		
v		

The term *molar concentration* is used to describe solution concentrations in the laboratory. It is a useful way of expressing concentration because you can use it to find the moles of solute dissolved or the volume of the solution you need in order to get a certain amount of dissolved solute.

6. a. Using the relationship $C = \frac{n}{v}$, solve the equation for the number of moles (n).
- b. Using the relationship $C = \frac{n}{v}$, solve the equation for the volume (v) of the solution.

Check your answers by turning to the Appendix, Section 2: Activity 1.



The following example problem illustrates the use of both the Formula Method and the Factor Label Method of solving problems.

Question: What is the concentration of solution made by dissolving 0.135 moles of $\text{NaCl}_{(s)}$ to make a 500 mL solution?

List of Variables: $C = ?$

$n = 0.135 \text{ mol NaCl}$

$v = 0.500 \text{ L}$ Note: The volume must be converted to litres. To do this move the decimal over three spaces.

Formula Method	Factor Label Method
if $C = \frac{n}{v}$ $C = \frac{0.135 \text{ mol}}{0.500 \text{ L}}$ $= 0.270 \text{ mol / L (three sig. dig.)}$	$C = 0.135 \text{ mol} \times \frac{1}{0.500 \text{ L}}$ $= 0.270 \text{ mol / L (three significant digits)}$

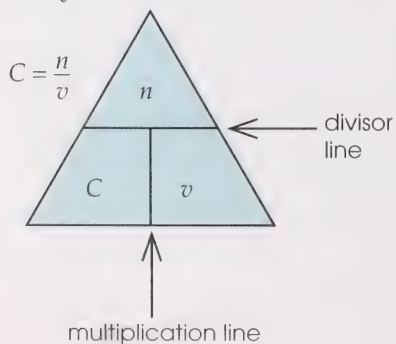
Do the following problems to practise molar concentration calculations. Use either method but show your work in detail. Make sure the answers are rounded to the correct significant digits.

- What is the molar concentration of a solution made by dissolving 1.20 mol of potassium nitrate in 2.00 L of water?
- What is the amount of solute in moles dissolved in 200 mL of 0.625 mol/L $\text{HCl}_{(aq)}$?
- What volume of 0.300 mol/L glucose solution contains 0.0800 moles of solute?

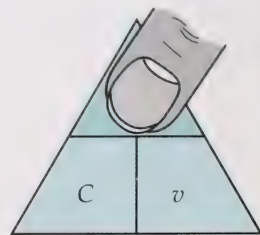
Check your answers by turning to the Appendix, Section 2: Activity 1.

Another way you can use the formula,

$C = \frac{n}{v}$, is in diagram form.

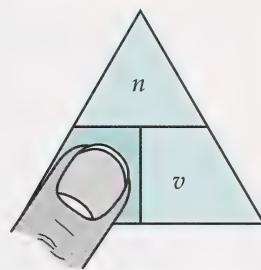


This type of diagram may be easier for you to use to solve problems. For example, if moles, n , is the unknown you are solving for, covering n (with your thumb or some object) shows you how to solve the problem – multiply $C \times v$.



In another example, if concentration, C , is the unknown, the problem is solved by dividing n by v . Whether or not you use this method of solving problems is up to you.

The relationship, $C = \frac{n}{v}$, uses the moles of solute in the calculation. In the lab however, the solute is measured on a balance using its mass. In some of the calculations you will need to change the moles of solute into mass, or vice versa.



10. How do you calculate the mass of a substance if you are given the moles?

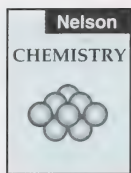
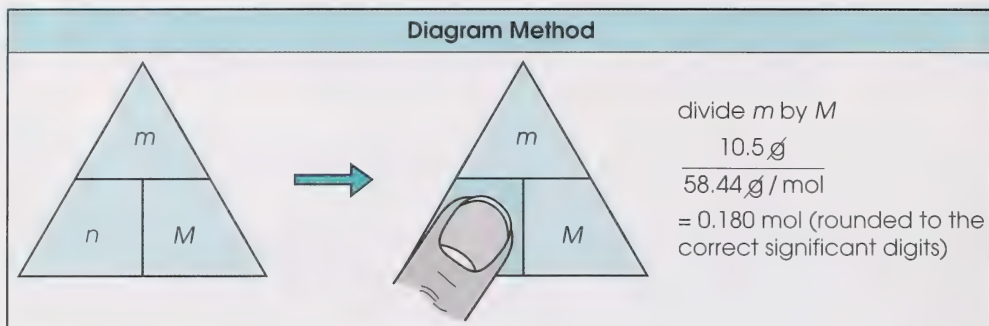
molar mass – the number of grams of a substance needed to make one mole; symbolized by M with units of g/mol

If you know the moles of solute, you can change it to mass using the **molar mass**. The mass can be found by multiplying the number of moles by the molar mass. This can be done by either using the Formula Method or by the Factor Label Method.

Formula Method	Factor Label Method
$m = nM$ where m = mass n = moles M = molar mass Note: When using formulas, the units should always be checked.	$m = n \text{ mol} \times \text{g/mol}$ $= \text{g}$ Notice that the mol units cancel to give the required unit g. The units automatically check the correct setup.

The amount of a substance is described in moles. When actually measuring a substance, mass in units of grams or kilograms is used. The following example problem reviews the conversion between mass and moles, as you learned in Science 10.

Question: What amount in moles is present in 10.5 g of $\text{NaCl}_{(s)}$? List of Variables: $n = ?$ $m = 10.5 \text{ g}$ $M = 58.44 \text{ g/mol NaCl}$	
Formula Method	Factor Label Method
if $m = nM$, then $n = \frac{m}{M}$ $n = \frac{10.5 \text{ g}}{58.44 \text{ g/mol}}$ $= 0.180 \text{ mol (rounded to correct significant digits)}$	$n = 10.5 \text{ g} \times 1 \text{ mol} / 58.44 \text{ g}$ $= 0.180 \text{ mol (rounded to correct significant digits)}$



For other examples of calculations, see pages 125 and 156 in your textbook.

Do the following three questions to practise converting between mass and moles. Use one of the problem solving methods previously described.

11. What mass is present in 0.215 moles of $\text{CaCl}_{2(s)}$?
12. a. What is the number of moles present in 15.3 g of $\text{Ca}(\text{ClO})_{2(s)}$?
- b. What is the number of moles present in 12.8 g of aluminum chloride?

Check your answers by turning to the Appendix, Section 2: Activity 1.

What is common between the relationships $C = \frac{n}{v}$ and $n = \frac{m}{M}$? You probably noticed that the term n dealing with moles is a variable in both formulas. This gives you some idea of how important moles are in many calculations you perform.

A relationship can be developed between all variables in both formulas and illustrated as in Figure 1.7.

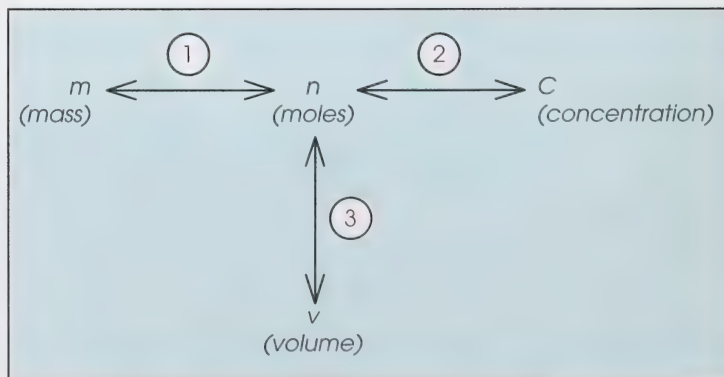


FIGURE 1.7: Variable Relationships

The relationship in Figure 1.7 shows that you can convert among all four variables. The circled numbers 1, 2, and 3 indicate the information needed to convert between any two variables.

- Conversion (1): needs the molar mass to do conversions between mass (m) and moles (n)

The following examples require molar mass to do the conversions:

- To convert 2.59 g of NaCl into moles of NaCl, you need the molar mass of NaCl, 58.44 g/mol, as a conversion factor to do the calculation.

$$n_{\text{NaCl}} = 2.59 \text{ g} \times \frac{1 \text{ mol}}{58.44 \text{ g}} = 0.0443 \text{ mol} \quad \text{or} \quad n_{\text{NaCl}} = \frac{2.59 \text{ g}}{58.44 \text{ g/mol}} = 0.0443 \text{ mol}$$

- To convert 0.0443 mol of NaCl into mass, you would use the molar mass of NaCl as a conversion factor again, but flipped over (to give g/mol).

$$m_{\text{NaCl}} = 0.0443 \text{ mol} \times \frac{58.44 \text{ g}}{1 \text{ mol}} = 2.59 \text{ g NaCl}$$

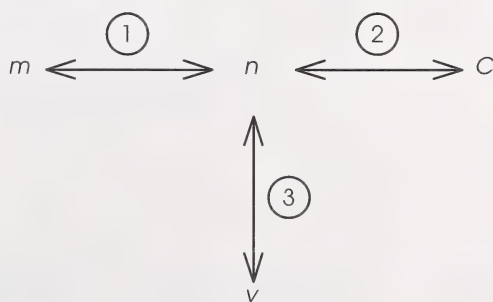
- Conversion (2): needs the volume to be given as information
- Conversion (3): needs the concentration to be given as information

13. Using the information in Figure 1.7, how would you find volume as an unknown, given the mass as the known variable? Explain your answer in words, equations, and conversion factors if necessary.

Check your answers by turning to the Appendix, Section 2: Activity 1.

As you have seen, when solving problems involving some combination of the four variables – mass, moles, concentration, and volume – two methods can be used: the Factor Label Method or the Formula Method. You could use the chart shown earlier in Figure 1.7 to help you if you prefer the Factor Label Method. If you prefer using formulas, a combination of

$$C = \frac{n}{v} \text{ and } n = \frac{m}{M} \text{ would be needed.}$$



Study the following example to see how these methods of calculation can be used.

Question: What is the mass of solute dissolved in 20.0 mL of 0.200 mol/L $\text{NaCl}_{(\text{aq})}$?

List of Variables: $n = ?$

$m = ?$

$M = 58.44 \text{ g/mol NaCl}$

$n = ?$

$v = 0.0200 \text{ L}$ (Note: The unit is litres.)

$C = 0.200 \text{ mol/L}$

Formula Method	Factor Label Method
if $C = \frac{n}{v}$, then $n = Cv$ $n = 0.200 \text{ mol/L} \times 0.0200 \text{ L}$ $= 0.00400 \text{ mol}$ $m = nM$ $= 0.00400 \text{ mol} \times 58.44 \text{ g/mol}$ $= 0.234 \text{ g}$ (rounded to correct significant digits)	- convert concentration to moles: $n = \frac{0.200 \text{ mol}}{\text{L}} \times 0.0200 \text{ L}$ $= 0.00400 \text{ mol}$ - convert moles to mass: $m = 0.00400 \text{ mol} \times \frac{58.44 \text{ g}}{1 \text{ mol}}$ $= 0.234 \text{ g}$ or chain the calculation in one line $m = \frac{0.200 \text{ mol}}{\text{L}} \times 0.0200 \text{ L} \times \frac{58.44 \text{ g}}{1 \text{ mol}}$ $= 0.234 \text{ g}$

chain – put all operations together in one line

Note: Even though intermediate step answers may be shown rounded in this course, final answers are based on unrounded values.

The advantages of the chained calculation in the Factor Label Method example are the following:

- No rounding is necessary until the final answer.
- Your calculator is not needed until the entire calculation is set up.

Do the following problems using your preferred method of calculation.

- What mass of barium chloride is needed to make 1.00 L of 0.600 mol/L $\text{BaCl}_{2(\text{aq})}$?
- What mass of dissolved ammonia is present in 25.0 mL of 0.500 mol/L $\text{NH}_{3(\text{aq})}$?
- What volume of a 0.100 mol/L barium nitrate solution contains 15.6 grams of dissolved solute?

Check your answers by turning to the Appendix, Section 2: Activity 1.

ACTIVITY

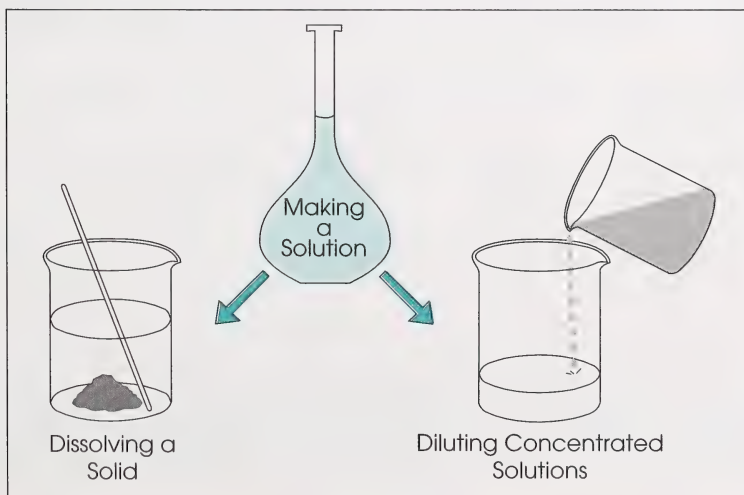
2

Preparation and Dilution

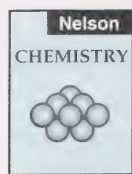
What do you need to know to make a proper solution? Does it matter how much lemon or sugar you use when making lemonade? In Section 1 you learned of three reasons why solutions are used instead of pure substances for reactions in solution.



In order to control reactions there should be a more accurate way of describing the amount of solute dissolved in the solution. There are certain procedures you must follow to prepare a solution with a known molar concentration.



There are two ways that you can prepare a solution. In this activity, you will make a solution by dissolving a solid in water. Secondly, you will make a solution by diluting part of a more concentrated solution.



To learn how to dissolve a solid to make a solution, read page 535 of Appendix C in your textbook, then answer the following questions.

1. How much water should you use to dissolve a solid?
2. Put these steps outlining the preparation of a solution in sequential (a, b, c) order.

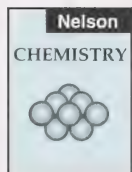
Preparing a Solution

- _____ Dissolve the solid in half the volume you need to prepare.
- _____ Fill the volumetric flask up to the calibration mark with distilled water.
- _____ Stopper the volumetric flask and invert several times to mix.
- _____ Measure the mass of the solid using a balance.
- _____ Transfer the solution to an appropriate volumetric flask.

3. Sketch a diagram of a volumetric flask.

Check your answers by turning to the Appendix, Section 2: Activity 2.

When you prepare a jug of lemonade, must you follow the directions exactly? You can be out a few drops of lemon juice and it will make no difference.



In solution chemistry, the exact concentration is often very important. So that you can review calculations involving the mass of the solute, read Section 7.6 Volumetric Techniques on pages 185 and 186 of your textbook. Then answer the following questions.

4. What is a standard solution?
5. What values do you need to know if you are calculating the mass of solid needed to make an aqueous solution?
6. a. If you are calculating the mass of solid needed for a solution, there are _____ steps involved.
b. What are the steps?

Check your answers by turning to the Appendix, Section 2: Activity 2.

To apply the ideas of calculating molar concentration and practise an accurate way of preparing solutions, do the following investigation.

Investigation 7.5: Preparation of a Standard Solution from a Solid

Carefully follow the directions given for this investigation on page 186 of *Nelson Chemistry*. Pay special attention to the required components, safety aspects, and applied science skills.

To do this investigation, change the solution you are making to 100 mL of a 0.200 mol/L $\text{CuSO}_{4(\text{aq})}$ solution. You will use this solution in the next investigation as a stock solution so remember to store it.

- Write the prelab calculation needed to prepare the solution.

Perform the remaining steps of the procedure.

- Describe the appearance of a 0.200 mol/L $\text{CuSO}_{4(\text{aq})}$ solution.
- Complete questions 36, 37, 38, and 39 from page 187 of your textbook.

Check your answers by turning to the Appendix, Section 2: Activity 2.

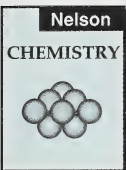
If you made a fruit drink and it was too strong, would you throw it out and start all over again?

Now that you have learned the methods of preparing a solution from a solid, you will try to prepare a solution by dilution.

- What does the term *dilution* mean to you?

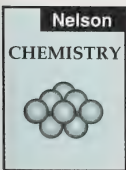
In a laboratory, it is often easier to dilute a concentrated solution than it is to prepare a solution from a solid.

To learn how to use the equipment needed to dilute a concentrated solution, read the section Using a Pipet on pages 532 and 533 of Appendix C in *Nelson Chemistry*. Then practise the processes described using the appropriate equipment. Use water as a material with which to practice.

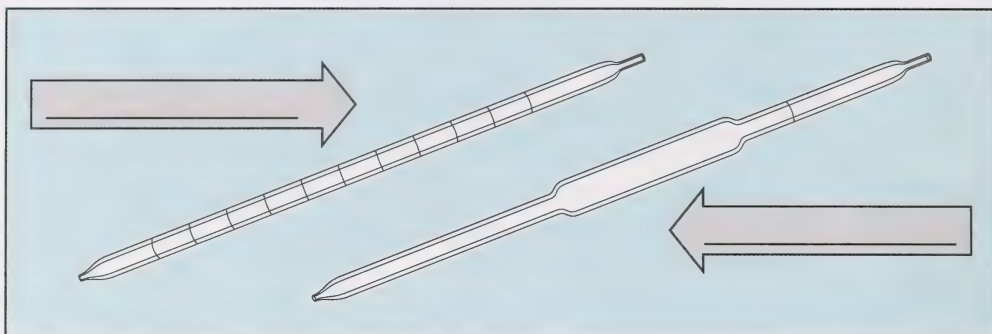


Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

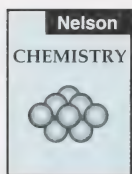


11. Label the graduated pipet and the volumetric pipet in the following figure.



Was your decision to throw away the fruit drink that was too strong? Most people would not. They water it down. To dilute the solution you prepared in the previous investigation, do the following investigation from page 188 of your textbook.

Investigation 7.6: Preparing a Standard Solution by Dilution



Carefully follow the directions given for Investigation 7.6 on page 188 of your textbook. Pay special attention to the required components, safety aspects, and applied science skills.

Perform the investigation with the following change.

Change step 1 of the procedure to read as follows:

Pour the 0.200 mol/L $\text{CuSO}_{4(\text{aq})}$ that you have prepared in Investigation 7.5 into a 150 mL beaker.

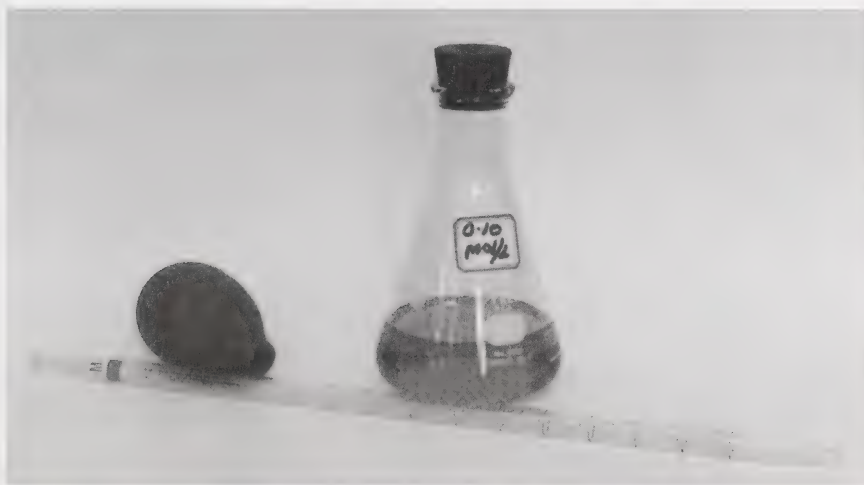
Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

12. How does the appearance of the dilute solution compare to the appearance of the concentrated solution it was made from?
13. Calculate the number of moles that you pipetted from the stock solution.
14. How does the moles of solute in the pipet compare to the moles of solute in the diluted solution?
15. Calculate the concentration of the solute in the dilute solution you prepared.

Check your answers by turning to the Appendix, Section 2: Activity 2.

16. For each of the following, indicate whether the statement is true or false.
- The final volume of the solution is the same as the volume of distilled water you add.
 - The moles of solute in the concentrated solution is greater than the moles of solute in the dilute solution.
 - The volume of the concentrated solution is less than the volume of the diluted solution.
 - The colour intensity of the dilute solution is less than the concentrated solution.
 - To find out how much distilled water is added, subtract the initial volume of the concentrated solution from the volume of dilute solution to be made.
 - If you needed to transfer 300 mL of the concentrated solution to the volumetric flask, you could use a graduated cylinder.
 - If you needed 72.0 mL of a standard solution, you could prepare the dilute solution in a beaker.



There is a simple mathematical formula that can be used when calculating volumes for dilution.

To learn the mathematical relationship used in dilution calculations, read the section Calculating Volumes for Dilution on pages 188 and 189 of your textbook. Answer the questions which follow.

17. What is the relationship used when calculating the concentration of a diluted solution?

18. Create a chart describing the variables of the dilution formula.

Symbol	Description	Units
V_i		

19. Rearrange the mathematical formula to solve the relationship for the final concentration (C_f).
20. Complete questions 40, 41, and 42 (a, b, c) from pages 189 and 190 of your textbook.

Check your answers by turning to the Appendix, Section 2: Activity 2.

Solutions that are made up to such exacting standards are used in quantitative analysis. If you know the amount of solute that reacts, then you can calculate the amount of the other reactant. For example, to find out the concentration of sugars in the urine, an alkaline copper(II) sulphate solution with a precise concentration is reacted with the sugars in the urine. The concentration of the copper(II) sulphate solution must be accurate to find out the concentration of the sugars. You will find out more about quantitative analysis in Module 4.

Now that you can make an aqueous solution from either a solid or a concentrated solution, you will be introduced to other ways of describing concentration.

ACTIVITY

3

Concentration and Accumulation

You have just learned about molar concentration, but is that the way concentration is described outside a laboratory? Sometimes concentrations are so low that specific units are developed for solutions which have solutes at very dilute concentrations. In environmental studies, for example, concentration is described as parts per million (ppm). This unit is commonly used for describing substances found in small amounts but are very harmful even at these concentrations.

You will learn more about these concentration units in Module 4.

Concentrations can be used to make decisions about certain chemicals or to monitor the environment for pollutants.

DID YOU KNOW?

Coal miners used to carry caged canaries into the mines with them. These small birds acted as a monitor of dangerous gases such as hydrogen sulphide. Humans cannot smell hydrogen sulphide even if the concentration of the gas is high, but canaries are very sensitive to the gas. If the canaries died, it was time to get out of the mine.

toxic –
poisonous or
harmful

heavy metals –
metallic elements
that have a high
density

herbicides –
chemicals that
kill plants

pesticides –
chemicals that
kill organisms
which compete
with man for food
or destroy stored
food

Toxic substances like hydrogen sulphide gas are poisonous substances. In solutions, they can be harmful in low concentrations. The way of describing their concentration is usually in units of parts per million. Toxic substances such as **heavy metals**, **herbicides**, and **pesticides** can be found throughout the environment in various concentrations.



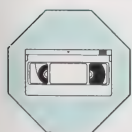
WESTFILE INC.

biomagnification
– accumulation
of substance in
the consumers of
a food chain

food chain – a
sequencing of
organisms on the
basis of energy
transfer or who
eats whom

Biomagnification is a process where toxins can collect in small animals and move up in the **food chain**. These toxic materials can be harmful to the health of any plant or animal.

View the video, *PCBs in the Food Chain*, to see a marine example of the growing problem of biomagnification. Then answer the following questions. You may find it will help your understanding if you preview the questions before watching the video.

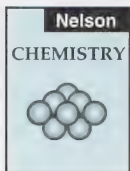


PCB –

polychlorinated biphenyl; organic toxic substance once commonly used, used currently as electrical transformer fluid

DDT –

dichlorodiphenyl-trichloroethane; pesticide that acts on the stomach of insects



amphipods –

smaller microscopic crustaceans

1. Describe the ocean regions where pollution is most often found and how that relates to the basic diet of most fish.
2. What significance is there in the fact that the basic organisms of the ocean first ingest various pollutants?
3. List one reason why dolphins were chosen in the study of the effects of pollutants.
4. Describe briefly the results of the dolphin study done in the Pacific.
5. How did the level of contaminants in the dolphins compare to the contaminant level in the sardines the dolphins ate?
6. List three properties of **PCBs** and **DDT** that make these chemicals particularly dangerous.
7. Name another animal that has shown signs of biomagnification besides dolphins and sardines.

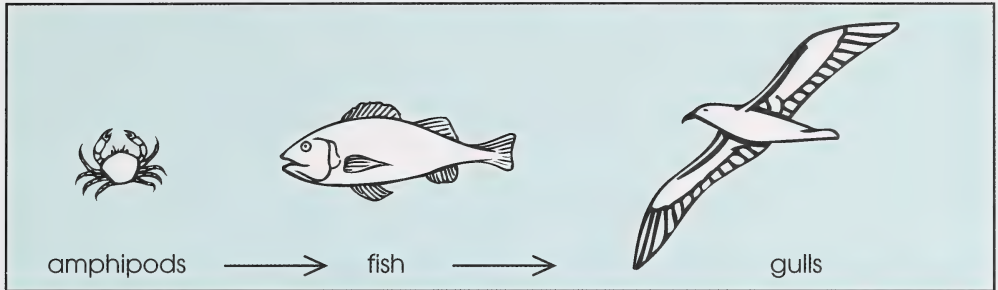
Read the article Biomagnification on page 130 of your textbook to learn more about these toxic substances that can collect in living organisms. Use this information to answer the question that follows.

8. Fill in the words missing from the following paragraph.

DDT or _____ is an insecticide that has serious side effects. Animals can absorb it in their _____. This means that the chemical can _____ in the animal. DDT would be most concentrated in animals at the top of a _____. When animals at the top of a food chain have a higher concentration of a substance than those animals lower down, _____ has happened. According to the chart on page 130, the concentration of DDT found in **amphipods** is _____ and the concentration of DDT in gulls is _____. This table shows that even though the concentration of the pesticide in the lake is _____, it is _____ in the living organisms.

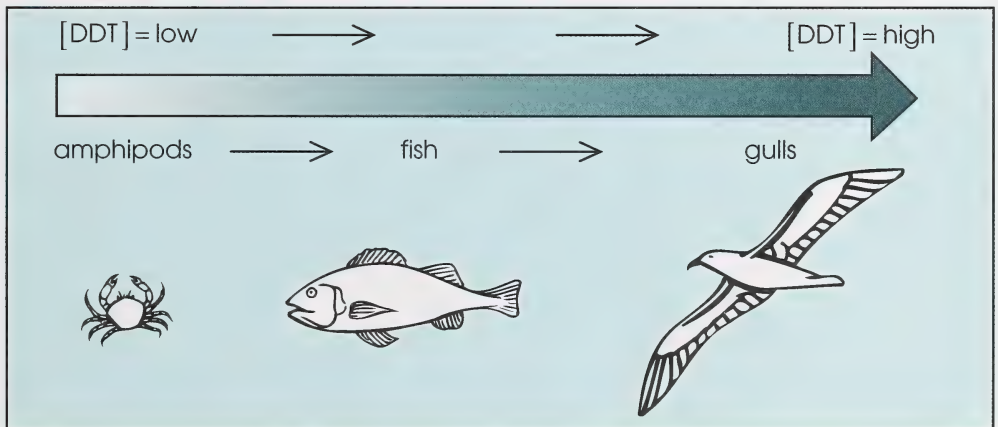
Check your answers by turning to the Appendix, Section 2: Activity 3.

The concentration of DDT in the amphipods compared to that in the gulls shows that DDT has become more concentrated as you go up the food chain. If you were to diagram the food chain, it would look like the following.



[] -
abbreviation for
concentration of
anything in the
brackets

If you were to show the concentration of the pesticide (abbreviated as [DDT]) along the food chain, the concentration of the substance would look like the following diagram.



Ecologists use this idea to keep track of pollutants. If toxic substances are measured lower down in the food chain, then maybe something can be done about the substance. For example, the larvae of aquatic flies could be a sample to identify where some sources of ecological hazards are in rivers and streams. Shellfish can be analysed for chemicals such as PCBs and pesticides in lakes and oceans.

In this way, animals lower in the food chain could act as the canaries in the coal mine.

You have seen how the concentration of a pesticide like DDT can be used to measure biomagnification in a food chain. The biomagnification of materials such as PCBs, herbicides, and pesticides is a problem that must be dealt with by society. The question needs to be asked, is the value of these toxins worth the risk?

ACTIVITY

4

Concentration—Variety and Risks

Have you thought about the causes of some of the dangers that exist when you use solutions? Are solutions more dangerous as they become more concentrated? How do you dispose of the solutions? All laboratory facilities have specialized containers which are sent away for disposal.

1. Define *concentrated solution*.
2. Define *dilute solution*.

Check your answers by turning to the Appendix, Section 2: Activity 4.

As you have discovered in Activity 3, some solutes that are dissolved in solution can be harmful even though their concentrations are in the order of parts per million. In laboratories, there are solutions that range from the very dilute to the highly concentrated.



FIGURE 1.8: Various Concentrations of Copper(II) Sulphate Solution

Some solutions and their concentrations that may be found in a high school laboratory are listed in the table that follows.

Name of Solution	Chemical Formula	Molar Concentration (mol/L)
lead(II) nitrate	$\text{Pb}(\text{NO}_3)_{2(aq)}$	0.100
copper(II) sulphate	$\text{CuSO}_{4(aq)}$	0.500
hydrochloric acid	$\text{HCl}_{(aq)}$	6.00
ammonia	$\text{NH}_{3(aq)}$	14.8

FIGURE 1.9: The Concentration of Solutions

3. Classify the four solutions listed in Figure 1.9 as either concentrated or dilute.

Check your answers by turning to the Appendix, Section 2: Activity 4.

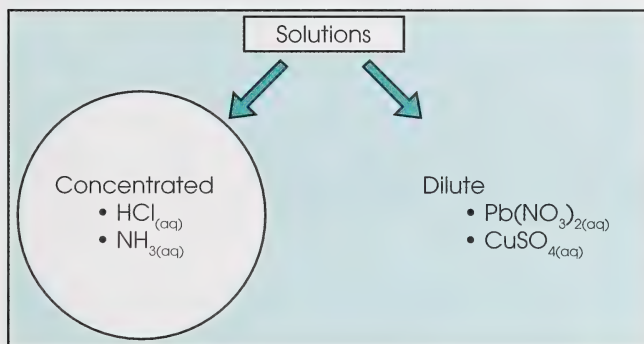


FIGURE 1.10: A Focus on Concentrated Solutions

Now that you have classified solutions as concentrated or dilute, focus on the nature of concentrated solutions in terms of the dangers they may present and the precautions needed when you use them in the lab.

The hydrochloric acid and ammonia solutions in Figure 1.10 are highly concentrated solutions.

4. What is the greatest danger involved in using highly concentrated solutions?

Check your answers by turning to the Appendix, Section 2: Activity 4.

corrosive –
something that
causes damage
to tissues

Spilling concentrated reagents is a serious matter. The immediate concern is whether or not some has landed on you. Concentrated solutions can be **corrosive**. Some reagents may also stain your skin.

If you have not spilled any on you, the next concern is to contain the spill. Many labs have acid pillows to absorb and neutralize acids. If the substance needs to be picked up immediately and is not an acid, it can be picked up by using kitty litter.

fume hood – a cabinet that contains an exhaust system that draws out air

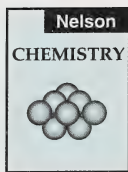
When working with concentrated solutions, some precautions may have to be taken that are not needed when the dilute form is used. For example, $0.100 \text{ mol/L HCl}_{(aq)}$ does not give off fumes like $11.6 \text{ mol/L HCl}_{(aq)}$. The concentrated solution is a respiratory hazard and you should always work with it in a **fume hood**.



Some of the many lab safety precautions for using concentrated solutions are the following:

- Wear an apron and eye protection.
- Always use a bulb to pipet solutions.
- Pour concentrated solutions into water. A good acronym to remember is the Triple A rule: Always Add Acid. This means that it is a good idea to add concentrated acid to water when diluting the acid. If you add water to concentrated acid, the solution can splatter.
- Dilute concentrated solutions before pouring them down a drain.
- Wash chemicals spilled on the skin with cool water for twenty minutes.
- Never drink or taste chemical reagents in the lab.
- Do not pour solutions down a drain unless you know that it is safe to do so.

A different method of disposing of some kinds of solutions will be discussed in Section 3.



Note: A more extensive list of general lab safety rules can be found on pages 540 to 542 of your textbook.

The preceding precautions are taken with the concentrated reagents, but they can also apply to all solutions. Concentration is not the only factor that you must consider when using solutions. What could make a solution dangerous if it is dilute? Other factors could include the reactivity of the substance, the stability of the substance, or the toxicity of the substance.

Now that the safety precautions on using concentrated solutions have been assessed, why do these precautions need to be taken with dilute solutions?

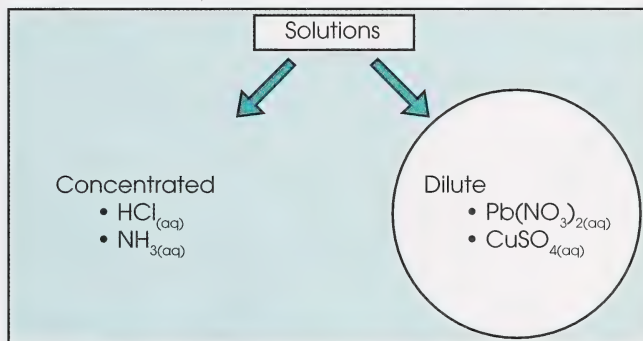


FIGURE 1.11: A Focus on Dilute Solutions

- List some possible hazards you may encounter by using solutions like lead(II) nitrate and copper(II) sulphate.

Check your answers by turning to the Appendix, Section 2: Activity 4.

Few chemicals in a high school laboratory are toxic. However, there are degrees of toxicity that range from being a mild irritant to being a poisonous substance. The effects of a toxic substance can be divided into two categories, chronic and acute.

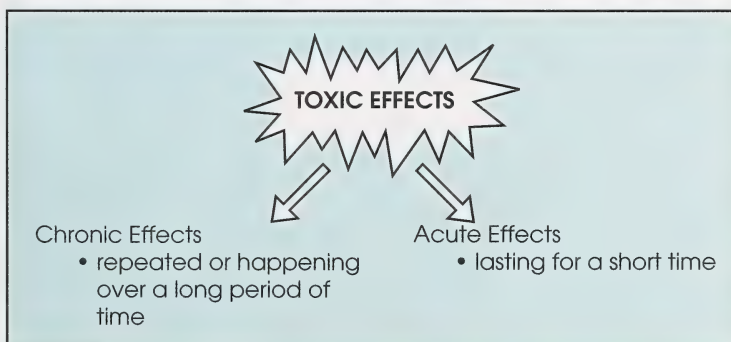


FIGURE 1.12: Toxic Effects

Fortunately, very few if any chemicals which produce chronic effects are present in a high school lab. Substances that cause cancer or mutations are examples of these toxic chemicals. Normally, there is little concern for chemicals which cause acute or short term effects in the lab because of these chemicals being in solution. You would have to drink the chemical solutions for them to have any effect and this is not recommended lab technique. Lead ions, for example, can cause heavy metal poisoning.

6. What precautions would you take in the lab to prevent acute effects of toxicity?

Check your answers by turning to the Appendix, Section 2: Activity 4.

The general procedures listed in this activity are not a complete list of all safety procedures. Safety in the lab is based on common sense precautions and not treatment of accident victims after the fact. To make sure that chemicals are not accidentally mixed together to produce a dangerous reaction, store and label solutions clearly and accurately.

As you have learned in Science 10, WHMIS suggests specific ways to label and store chemical substances.

7. a. Can you suggest how the 6.0 mol/L bottle of $\text{HCl}_{(\text{aq})}$ in the photograph could be labelled more accurately according to WHMIS guidelines?
- b. What information should your labelling contain?

Now you know that substances can be toxic whether or not they are concentrated or dilute. Toxic substances do not only exist in a lab, they are all around you in various concentrations. As you learned in Section 1, tooth fillings are alloys which contain mercury, a highly toxic substance.



Do you have mercury or silver dental fillings? A controversy has been growing over the past few years about the safety of dental fillings which use mercury. In 1992, Germany banned the use of mercury in dental fillings.

Mercury is a highly toxic substance that causes nerve damage yet is present in the environment. People pass 0.0076 mg of mercury in their urine daily. There are maximum concentrations recommended for mercury in drinking water. In Alberta, the maximum concentration is 0.001 mg/L.

To learn more about the controversy surrounding tooth fillings, read the following article, “Mercury Leak”.

As you read, fill out the inventory following the article. In the plus-points column, fill in some information that supports the use of mercury fillings. In the minus-points category, fill in some information that goes against the use of mercury fillings. In the interesting-points category, write down some things that you find interesting about the article. You will be using your inventory in a later question.

Mercury Leak

American study backs claim that most mercury in body comes from dental fillings

By Mark Lowey

(Herald writer)

People are exposed to more mercury from tooth fillings than from diet or any other source, says a new American study prompted by Calgary scientists' research.

More studies should be conducted to determine whether there's enough mercury leaking from the widely used fillings to harm people, says University of Arizona toxicologist and study leader Dr. Vasken Aposhian.

“We don't know” whether the fillings are causing illness or disease, he said from Tucson.

“What we do know is that mercury is one of the most toxic substances around . . . there's no question more research should be done.”

The U of Arizona study found two-thirds of the mercury in urine of people who have the fillings came from mercury vapour released by the restorative material.

Vapour escapes when people chew, grind or brush their teeth, and as the silver-coloured fillings – called dental amalgams – deteriorate with age.

People absorb between three to 17 micrograms of mercury per day from dental amalgam vapour, says a UN World Health Organization report on mercury.

“A great deal of the mercuric mercury was deposited finally in the kidneys,” says the U of Arizona study.

But, it says, “there is no unequivocal evidence that such amounts of mercury in the human body are harmful to the individual's health.”

The study is published in the prestigious Federation of American Societies for Experimental Biology Journal, whose editorial board includes Nobel Prize winners.

But a spokesperson for the Canadian Dental Association says people shouldn't worry about the amalgam fillings, made of a metal alloy containing 45- to 50-percent mercury.

“We have no reason to be concerned, said Dr. Ralph Barolet, chairman of the association's committee on dental materials.

The U.S. Food and Drug Administration and the U.S. National Institutes of Health have decided the fillings are safe, he said, “and we have no reason to believe otherwise.”

Last August, a scientific panel from two branches of the National Institutes of Health said there's no solid scientific evidence showing the amount of vapour escaping from fillings causes any illness.

More study is needed, but "the present evidence suggests that the degree of exposure to mercury via dental amalgam is insufficient to be considered a health risk in virtually all individuals," said the panel's report.

A separate panel from the Food and Drug Administration reached essentially the same conclusion last April, although it also recommended more research.

Both panels' opinions are at odds with several peer-reviewed, published scientific studies by medical researchers at University of Calgary and elsewhere.

U of C research has shown dental mercury impairs kidney function in sheep, and that it collects in the kidneys, digestive tract and other organs of sheep and monkeys.

When the local research was first reported 1 1/2 years ago, the American Dental Association claimed dietary mercury in a tuna fish salad might be a bigger source of mercury exposure than dental fillings.

The U of Arizona study shoots down that claim, says U of C medical researcher Dr. Fritz Lorscheider. "If amalgams were not used, the levels of mercury in the human body would only be one-third of what they are now."

"There's a risk associated with all heavy-metal exposure," Lorscheider noted.

There are now at least six North American universities, including U of C, investigating possible health hazards of dental mercury.

University of Kentucky's Sanders-Brown Centre on Aging just received a National Institutes of Health grant worth more than \$800,000 over five years, to investigate a

possible link between dental mercury and Alzheimer's disease.

U of Kentucky scientists have found abnormally high levels of mercury in the brains of autopsied Alzheimer's victims.

In Sweden, research has shown people's kidney function improves after the fillings are removed. Also in Swedish studies, there are signs of impaired brain development and learning ability in laboratory animals exposed to mercury vapour.

In the latest study at U of Arizona, scientists gave an orally administered 'chelating' drug to two volunteer groups, each consisting of 10 university students.

The drug, called DMPS, chemically binds with and removes mercury from body tissues.

The drug is not approved for treating patients in Canada or the U.S., although it is used in Russia and Germany. U of Arizona scientists obtained a special licence to use DMPS in research.

Even before receiving the drug, 10 students with amalgam fillings had almost three times more mercury in their urine compared with 10 students without fillings.

Nine hours after getting the drug, the fillings group excreted 3.4 times more urinary mercury compared with the non-fillings group.

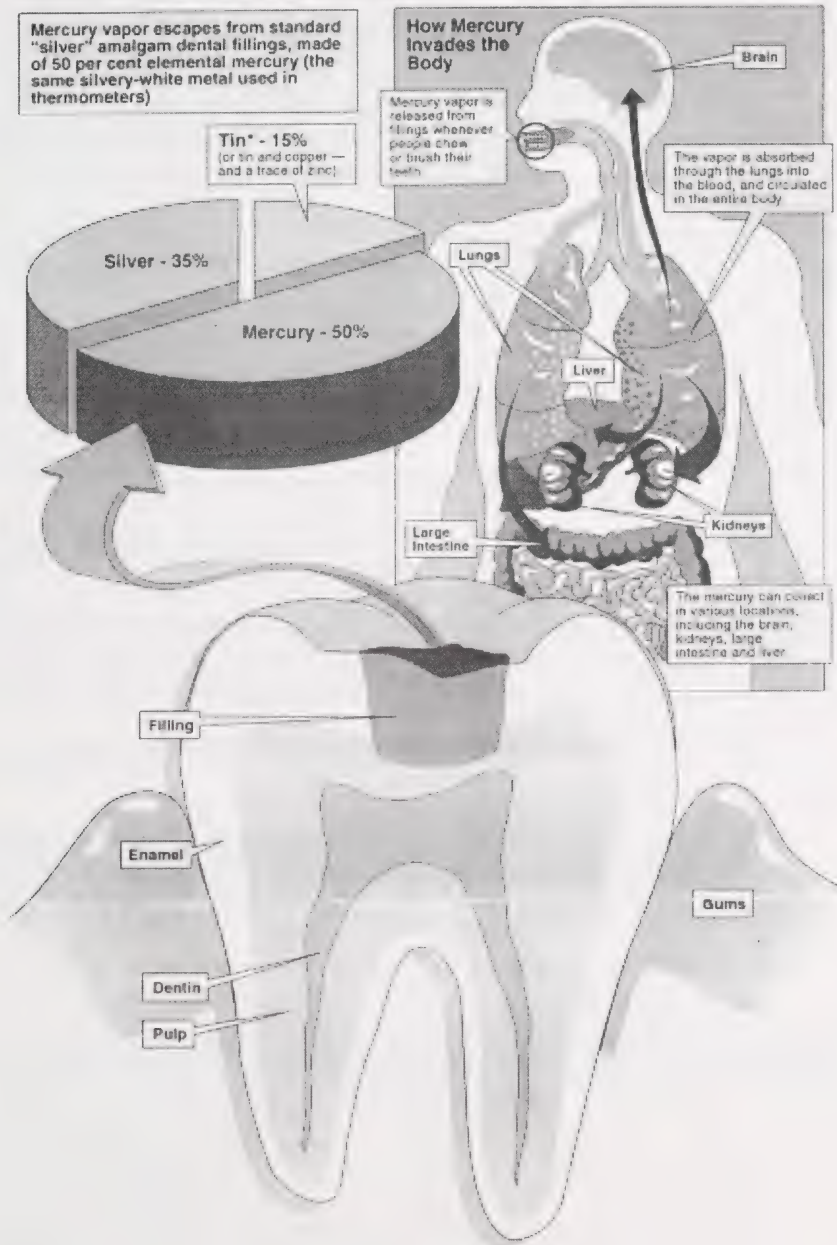
A statistical check revealed a strong correlation or match between the number of amalgams the fillings group had, and the amount of mercury in the urine.

"There's no question that there is a relationship between the surface area of the amalgams and the amount of mercury in the body," said study leader Aposhian.

He said DMPS should be investigated as a potentially useful tool to measure the amount of mercury and other heavy metals such as lead and arsenic in the human body.¹

¹ Mark Lowey, "Mercury Leak," *The Calgary Herald*, 23 May 1992, G9. Reprinted by permission.

SILVER AMALGAM DENTAL FILLINGS



¹ "Silver Amalgam Dental Fillings," *The Calgary Herald*, 23 May 1992, G9. Reprinted by permission.

Inventory

ISSUE: SHOULD MERCURY BE USED IN DENTAL FILLINGS?		
Plus-points Points which support use of Hg	Minus-points Points which oppose use of Hg	Interesting points

8. a. Mercury is passed in the urine of people with fillings. What fraction is caused by dental amalgams?
- b. How does mercury vapour escape from fillings?
- c. According to the UN World Health Organization, _____ of mercury is absorbed by people daily from dental amalgam vapours.
9. List three organizations that have decided mercury fillings are safe.
10. List three universities that are researching the effects of mercury in dental fillings.
11. If you have many fillings in your mouth, what does this mean about the amount of mercury found in your body?

Check your answers by turning to the Appendix, Section 2: Activity 4.

risks –
dangerous
elements or
factors

In the next part of this activity, you will be performing a qualitative assessment of the **risks** of mercury fillings, based on the mercury filling article you have examined. A risk assessment allows you to make careful judgements on important issues. The issue you will try resolving is the following: Should I remove the fillings in my mouth and have them replaced with gold or porcelain fillings?

The next two questions will guide you through the steps involved in performing a risk assessment. Use the points you entered in your inventory.

benefits –
factors that are
helpful or
promote well-
being

12. a. List the risks involved in removing and replacing the fillings.
- b. List the **benefits** involved in removing and replacing the fillings.

- c. Your next task is to decide whether the benefits of mercury fillings outweigh the risks. This decision will depend on the number of benefits compared to the number of risks and how important you perceive each risk and benefit to be. The end decision is yours and you should be able to back up your decision with reasonable arguments and evidence.
13. Based on the risk assessment you have performed, would you have your fillings removed and replaced? Explain.

Check your answers by turning to the Appendix, Section 2: Activity 4.

In this activity, you have discovered the necessity for precaution with various types of solutions. Precautions are also needed when dealing with toxic substances. You will probably have to make several judgements in your lifetime of whether the usefulness of some things outweighs the risks.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

- To calculate the number of moles present in a solid you divide the _____ by the _____. To find the number of moles of solute present in a solution you multiply the _____ by the _____.
- Complete the following table by filling in the blank spaces.

Solution	Molar Concentration	Volume of Solution	Moles of Solute	Mass of Dissolved Solute
ethanol solution	0.300 mol/L	25.0 mL		
KI _(aq)	0.200 mol/L	175 mL		
Na ₂ SO _{4(aq)}		1.50 L		9.35 g
CaCl _{2(aq)}		2.00 L	0.800 mol	

3. Match each of the following definitions to its proper term.

Definitions	Terms
a. the number of litres of concentrated solution to which water is added	i. beaker
b. substances collect in the consumers of an ecosystem	ii. biomagnification
c. transfers a set volume each time	iii. colour intensity
d. the litres of both the concentrated solution and the water used to dilute the solution	iv. volumetric pipet
e. container used to make a standard solution	v. dilution
f. can measure various volumes accurately	vi. food chain
g. a qualitative property of some solutions	vii. final volume
h. description used in laboratory situations to describe the amount of solute dissolved	viii. graduated pipet
i. a measure of how poisonous a substance is	ix. initial volume
	x. molar concentration
	xi. toxicity
	xii. volumetric flask

4. A technician is asked to make a 0.500 mol/L ammonia solution using 14.8 mol/L solution. She prepares a 2.00 L solution as described in the following paragraph. Fill in the missing information in the spaces provided.

To prepare the 0.500 mol/L solution the technician uses a 2.00 L _____.
 _____, She fills it half full of _____ before she begins the dilution.
 Then she takes _____ mL of the concentrated solution using a
 _____. She delivers this volume into the container and then adds enough
 _____ to bring the level of the solution up to the mark. Then she
 _____.

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

Do **one** of the following questions.

1. Biologists have discovered toxic substances such as mercury and PCBs in the livers of polar bears. Evidence suggests a trend. Bears in the extreme north have lower concentrations of these substances than polar bears further south. Investigate the food chain of the polar bear and propose a hypothesis about the source of these substances and the reason for the different concentrations.
2. PCBs (polychlorinated biphenyls) are found everywhere in the environment. These highly toxic substances bioaccumulate and have been found to cause cancer, poison the immune system, and severely affect reproduction. Currently, PCBs are used by electrical utilities and the pulp and paper industries. Research the uses of PCBs and find out how they have entered the biosphere.
3. Colour film processing involves a vast number of chemicals and solutions. Many retailers have film processors which develop film in a matter of hours. Telephone or visit a fast film processing business and find out how the solutions are handled and disposed.

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

There are many solutions that you deal with on a daily basis. One good example is tap water or well water. Some solutions and materials need more caution than others. With due care and attention, all solutions can be prepared and handled safely. It is up to you to be informed and prepared to deal with these materials effectively.

Assignment
Booklet

ASSIGNMENT

Turn to Assignment Booklet 1A and do the assignment for Section 2.

SECTION

3

Dissociation and Equilibrium



You may enjoy viewing the “icicles” when wandering through a cave, but do you have problems with the scale deposited on your humidifier, in your iron, or in your tea kettle? “Hard” water may taste good when you drink it but it deposits solids that can be bothersome. Many people put in water softeners in their homes to prevent the forming of a crust on their furnace humidifiers. Some people buy distilled water to use in their irons.

The culprit of this inconvenience is an ionic solute that dissolves poorly in the water. It deposits when the water evaporates. When the concentration of this solute is high enough, it forms a hard crust that is difficult to remove.

In this section, you will learn about solutes that deposit because they dissolve poorly. You will learn about the type and number of ions present in a solution. Finally, you will learn about a theory which explains how these particles interact.

ACTIVITY

1 Solubility

Organizing the vast amount of scientific knowledge discovered by scientists performing measurements and experiments is a difficult and complex task.

Experiments are often repeated many times to verify the results. Scientists and technicians may use organized data tables to help them in their daily tasks. One of these organizers is the periodic table.

Periodic Table of Elements

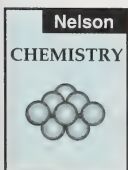
1 H hydrogen																	2 He helium				
3 Li lithium	4 Be beryllium															5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
11 Na sodium	12 Mg magnesium															13 Al aluminum	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton				
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon				
55 Cs cesium	56 Ba barium	71 Lu lutetium	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon				
87 Fr francium	88 Ra radium	103 Lr lawrencium																			
57 La lanthanum	58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 <i>Pm</i> promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb terbium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium								
89 Ac actinium	90 Th thorium	91 Pa protactinium	92 U uranium	93 <i>Np</i> neptunium	94 <i>Pu</i> plutonium	95 <i>Am</i> americium	96 <i>Cm</i> curium	97 <i>Bk</i> berkelium	98 <i>Cf</i> californium	99 <i>Es</i> einsteinium	100 <i>Fm</i> fermium	101 <i>Md</i> mendelevium	102 <i>No</i> nobelium								

Note: The preceding periodic table does not illustrate the most recent elements discovered. For a more complete periodic table, consult the inside cover of your textbook.

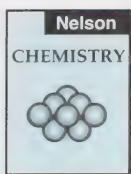
- Using the periodic table on the inside front cover of your textbook, list five pieces of data that are organized on the table.

Another valuable table which organizes data is a **solubility** table. An example of a solubility table can be found on the inside back cover of your textbook.

In this activity, you will be performing reactions to see how a table of solubilities is organized. You will then use the solubility chart to help you identify the ions present in a solution.



solubility – how well a substance dissolves



In Science 10, you were introduced the concept of solubility. To review this concept, read page 133 of *Nelson Chemistry* and then complete the questions that follow.

2. Identify the following statements as true or false.
 - a. You can dissolve more solute into a saturated solution at the same temperature.
 - b. Concentration can be used to describe solubility.
 - c. An unsaturated solution has the maximum concentration of solute dissolved.
 - d. If you add more solvent to a salt solution containing the maximum concentration, the solution will become unsaturated.
 - e. Diluting a saturated solution results in an unsaturated solution.
 - f. Solubility describes how well a solute dissolves.

If a substance dissolves easily in water, then it is highly soluble and forms an aqueous solution. If a substance is a poor dissolver, then it has low solubility and remains mostly as a solid.

3. What is the term for a solid that forms when two aqueous solutions have reacted?

Check your answers by turning to the Appendix, Section 3: Activity 1.

precipitate – a solid formed during the reaction of two solutions

A **precipitate** usually forms quickly and has a low solubility. It dissolves poorly compared to the aqueous solutes that have reacted to form it. In the following investigation, you will be reacting eight aqueous solutions to see what kinds of precipitates form.

Investigation: Precipitation Reactions

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

Carefully follow the directions given for this investigation. Pay special attention to the required components, safety aspects, and applied science skills.

Problem

Are there certain kinds of compounds that form precipitates?

Prelab

The eight solutions in this investigation are all soluble ionic compounds dissolved in water. Their solubility is greater than 0.10 mol/L.

4. What is common about the formulas for NaOH , Na_2CO_3 , Na_3PO_4 , and NaCl compounds?
5. What is common about the formulas for $\text{Ba}(\text{NO}_3)_2$, $\text{Ca}(\text{NO}_3)_2$, NaNO_3 , and $\text{Cu}(\text{NO}_3)_2$ compounds?
6. What generalization concerning solubility might be made about other compounds containing factors common to the compounds in the preceding two questions?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Guidelines

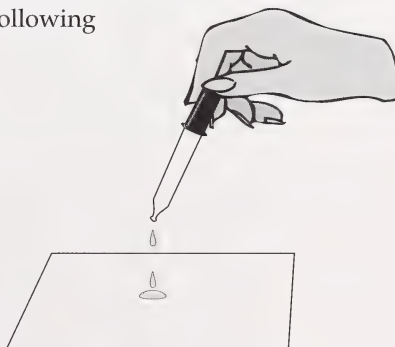
- Read the entire investigation, including questions, before starting the procedure.
- For this investigation you can use spot plates, an acetate sheet, or test tubes. The procedure here will be based on using an acetate sheet.
- Use an equal number of drops or equal volumes of the solutions.
- Make sure that the eye dropper is completely clean before you dip it into one of the other solutions.
- Use a toothpick for stirring the mixtures.

Materials

- bottles containing 0.10 mol/L solutions of the following

– Na_2CO_3	– $\text{Ba}(\text{NO}_3)_2$
– NaOH	– $\text{Ca}(\text{NO}_3)_2$
– Na_3PO_4	– NaNO_3
– NaCl	– $\text{Cu}(\text{NO}_3)_2$

- droppers or micropipets
- acetate sheet
- distilled water
- toothpicks



The following table can be used as a template over which you can place an acetate sheet and perform the procedure. The table can also serve as a model for your evidence table.

Place the acetate sheet over this table.				
	NaOH	Na ₃ PO ₄	Na ₂ CO ₃	NaCl
NaNO ₃				
Ba(NO ₃) ₂				
Ca(NO ₃) ₂				
Cu(NO ₃) ₂				

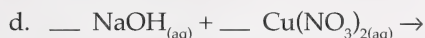
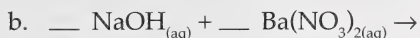
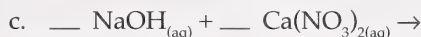
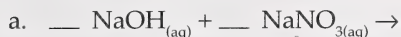
FIGURE 1.13: Procedure and Evidence Table

Procedure

- Place an acetate sheet over the table in Figure 1.13 so that you have a surface on which to mix the solutions.
 - Mix two drops of NaOH_(aq) with two drops of NaNO_{3(aq)} over the appropriate box on the table and stir carefully with a toothpick. Observe what happens.
7. a. Construct your own evidence table similar to Figure 1.13 and record in the appropriate space whether or not a precipitate forms when NaOH_(aq) and NaNO_{3(aq)} are mixed.
- b. Continue reacting the NaOH_(aq) with the other three solutions down the column in the observation sheet. Remember to use an equal number of drops of each solution for each reaction. Record your observations in your evidence table.

8. Before completing the remaining reactions, complete the double replacement equations for the first four mixtures that you have done.

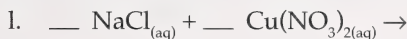
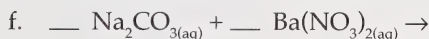
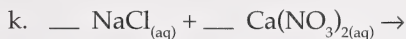
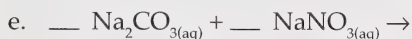
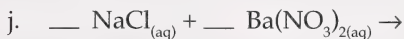
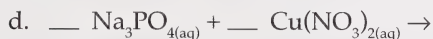
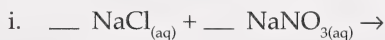
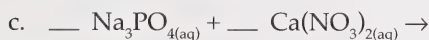
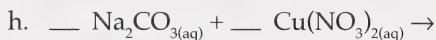
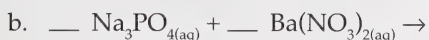
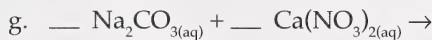
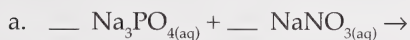
Balance the equations and use the solubility table to predict the states of the products. Note that two of the reactions should produce solid products. Also note that a coefficient need not be written if the balancing coefficient is one (1).



9. How did you know that the precipitate was $\text{Cu(OH)}_{2(s)}$ when $\text{NaOH}_{(aq)}$ was reacted with $\text{Cu(NO}_3)_2(aq)$?
10. a. List any precipitates formed in the first four reactions. What does this say about hydroxide compounds?
- b. Did you obtain any unexpected results? Explain.

Check your answers by turning to the Appendix, Section 3: Activity 1.

11. Now that you have completed the first four reactions, perform the remaining reaction combinations. Complete your evidence table by recording your observations.
12. Complete and balance the double replacement equations for the preceding reactions. Include the appropriate states for the products.

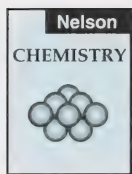


13. a. Which phosphate compounds have low solubility?
- b. Which carbonate compounds have low solubility?
- c. Which chloride compounds have low solubility?

14. a. What types of compounds used in this investigation are always soluble?
b. What types of compounds in this investigation have low solubility?
15. a. On the basis of the reactions done in this investigation, predict whether calcium phosphate would dissolve easily in water.
b. How well would sodium acetate dissolve?

Check your answers by turning to the Appendix, Section 3: Activity 1.

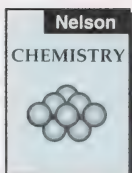
By doing this investigation, you have determined a way of linking a precipitate to the ability of an ionic compound to dissolve. The solubility chart on the inside back cover of your textbook is a way of organizing the data from this investigation as well as other evidence from other precipitation reactions.



Read page 104 of *Nelson Chemistry* up to the section Single Replacement Reactions to learn how to use this solubility chart for determining the solubility of an ionic compound. Then complete the following question.

16. You are given the following ionic compounds: $\text{NaI}_{(s)}$, $\text{AgOH}_{(s)}$, $\text{PbSO}_{4(s)}$, $\text{BaCO}_{3(s)}$, and $\text{Al}(\text{NO}_3)_{3(s)}$.
a. Which compounds are soluble?
b. Which compounds have low solubility?

In Section 1, you identified ions on the basis of colour and on the basis of a flame test result. Knowing that a solution will react to form a precipitate is another way that the identity of ions can be discovered.



To learn how to use the solubility chart to identify an ion qualitatively, read the section Qualitative and Quantitative Analysis on pages 121 and 122 of your textbook. Pay special attention to the example in the margin on page 122. The example illustrates in chart form how the analysis process works. Then answer the question which follows.

17. According to Figure 5.8 on page 122, when you test for the presence of an ion, another solution is added to _____ the ion from the solution. If two ions are present, then the solution you choose to react should _____ one ion but not the other. If the precipitate happens in the first step, then you must _____ it before you test for the presence of the other ion.

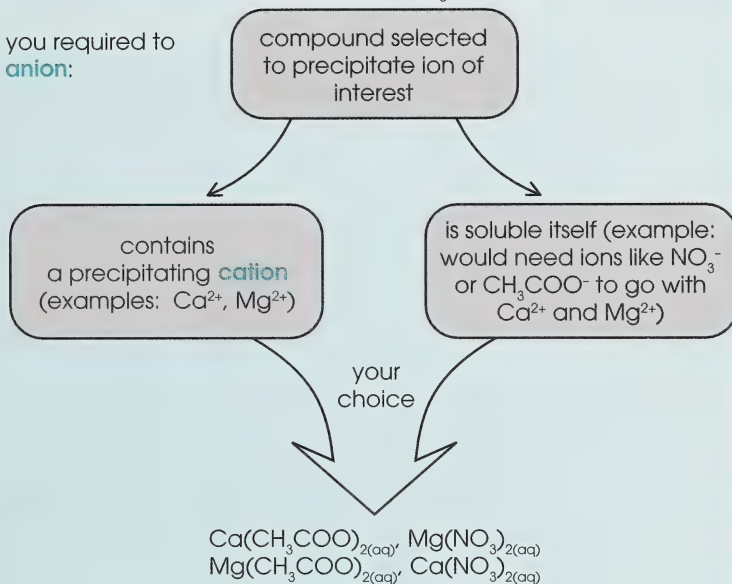
Check your answers by turning to the Appendix, Section 3: Activity 1.

When you select a compound to precipitate a specific ion of interest in solution, that compound has to meet two conditions:

- The compound must contain an ion that will precipitate with the specific ion of interest.
- The compound itself must be soluble so that its ions will be able to interact with other ions in solution.

Example: If the ion of interest you required to precipitate was an **anion** (example: CO_3^{2-})

If the ion of interest you required to precipitate was an **anion**:

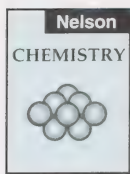


If any of these preceding compounds were mixed with a solution containing CO_3^{2-} , a precipitate containing CO_3^{2-} would form. This would remove the CO_3^{2-} from solution, which was your original goal.

18. Complete a precipitation table by filling in the required ions and selecting a compound you can use to form a precipitate.

Ion Present	According to the Solubility Chart it has low solubility with . . .	Precipitates with an aqueous solution of . . .
Hg^+		
Br^-		
CO_3^{2-}		

Check your answers by turning to the Appendix, Section 3: Activity 1.

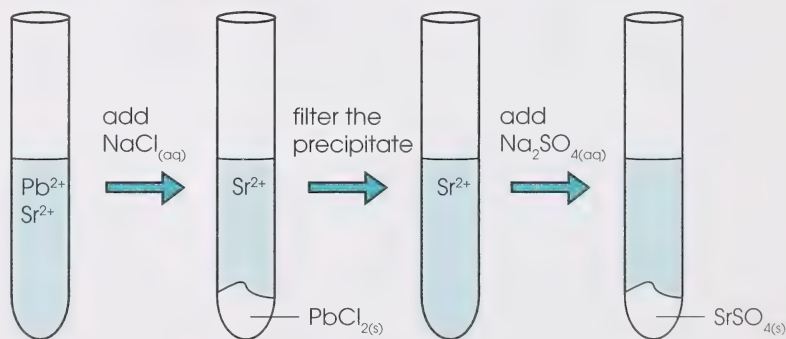


selectively precipitate – precipitate one ion of choice while leaving other ions in solution

When choosing a method to **selectively precipitate** an ion from a mixture of ionic compounds, this often involves more than one step. You have already read about this type of process on pages 121 and 122 of your textbook. Review these pages, as well as Figure 5.8, to gain a better understanding of the process. You will be using this analysis technique in the next investigation.

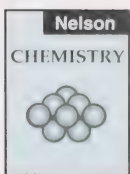
The solutions you will be using in Investigation 5.3 selectively precipitates lead(II) ions from strontium ions. Read the description of Investigation 5.3 Sequential Qualitative Analysis on the bottom of page 122 in your textbook. Then look at the following table which summarizes the choices made in the investigation.

Solution	Possible ions present	Ions that selectively precipitate one ion or the other	Choice and Reason
Unknown Solution Sample in Investigation 5.3	Pb^{2+}	Cl^- , Br^- , I^- , SO_4^{2-} , S^{2-} , OH^- , PO_4^{3-} , SO_3^{2-} , or CO_3^{2-}	Cl^- , Br^- , I^- will remove the lead(II) ions.
	Sr^{2+}	SO_4^{2-} , S^{2-} , OH^- , PO_4^{3-} , SO_3^{2-} , or CO_3^{2-}	None will selectively precipitate this ion.



$\text{NaCl}_{(\text{aq})}$ was used in the first diagnostic test since the $\text{Cl}^-_{(\text{aq})}$ ions could precipitate lead(II) ions and not strontium ions. You can only test for strontium ions if all the lead(II) ions are gone. Then the sulphate ions can be added by means of $\text{Na}_2\text{SO}_{4(\text{aq})}$ to react with any strontium ions present.

Investigation 5.3: Sequential Qualitative Analysis



Perform Investigation 5.3 as described on page 122 of your textbook. Carefully follow the directions given for this investigation. Pay special attention to the required components, safety aspects, and applied science skills.

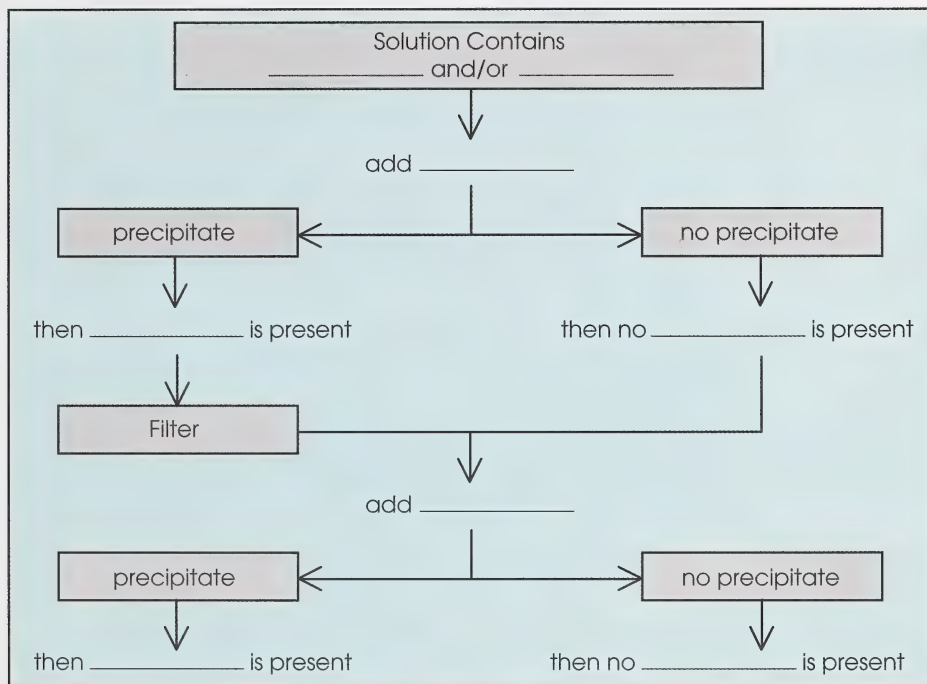
Guidelines

Science Skills

- ☒ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

- Note that the volumes of the solutions are not important. However, you must add at least equal volumes of solution.
- Make sure the precipitation has stopped by adding a few extra drops of solution. If no more cloudiness appears, then you know all the ions have been taken out of the solution.

19. Before you begin this investigation, fill out the following flow chart to help you map out the procedure.



20. a. Make a list of materials you need.
- b. List the steps in your procedure.
- c. Prepare a data table to record your evidence.

Check your answers by turning to the Appendix, Section 3: Activity 1.

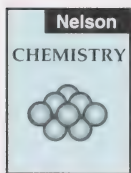
21. Write a brief analysis of your findings.

Check your answers by turning to the Appendix, Section 3: Activity 1.

Now that you have practised the techniques involved in selective precipitation, do the following questions.

22. Complete the following chart by choosing a compound to selectively precipitate an ion in the unknown solution. Mixture 1 has been completed as an example.

Mixture	Possible Ions Present	Ions Present Have Low Solubility with . . .	Compound(s) that Selectively Precipitate Ions Present
1 example	Ti^+	Cl^- , Br^- , I^- , S^{2-} , CO_3^{2-} , PO_4^{3-} , SO_3^{2-}	soluble compounds of Cl^- , Br^- , I^- , S^{2-} , e.g., NaCl , KBr
	Ra^{2+}	OH^- , SO_4^{2-} , CO_3^{2-} , PO_4^{3-} , SO_3^{2-}	soluble compounds of OH^- , SO_4^{2-} , e.g., KOH , Na_2SO_4
2	SO_4^{2-}		
	Cl^-		
3	CH_3COO^-		
	Cl^-		



23. Do textbook question 10 from page 123 of your textbook.
24. Do textbook question 19 from page 140 of your textbook.

Check your answers by turning to the Appendix, Section 3: Activity 1.

Selective precipitation is useful when you wish to discard solutions, but need to first remove a certain ion. For example, you may wish to dispose of a photographic intensifier. This is a solution used to develop film. The intensifier makes the image darker. You would first want to precipitate the silver ions from this solution because of their toxicity.

25. How would you remove the silver ions from a photographic solution before disposing of it?
26. How would you remove the lead ions from a waste container in a laboratory?

Science Skills

- ☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☒ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

27. Four solutions are known to contain four different ions. Solutions A, B, C, or D contain either Ba^{2+} , Li^{+} , Cu^{2+} , or Ag^{+} . All the solutions have a concentration of 0.100 mol/L . An experiment was performed to identify these solutions. The evidence is contained in the following data chart.

Write an analysis to identify which solution contains what ion and explain your reasoning.

Solution	Colour	Colour of Flame Test	Precipitate formed with $\text{Na}_2\text{SO}_{4(aq)}$?
A	none	yellowish green	yes
B	blue	blue-green	no
C	none	red	no
D	none	none	yes

Science Skills

- ☒ A. Initiating
☐ B. Collecting
☐ C. Organizing
☐ D. Analysing
☒ E. Synthesizing
☐ F. Evaluating

28. Design an experiment that will identify these three solutions from one another: $\text{K}_2\text{Cr}_2\text{O}_{7(aq)}$, $\text{Na}_2\text{SO}_{4(aq)}$ and $\text{NaCl}_{(aq)}$.

Check your answers by turning to the Appendix, Section 3: Activity 1.

You have discovered how various techniques can be used to identify and isolate specific substances. Many toxic or poisonous ions can be treated using these methods.

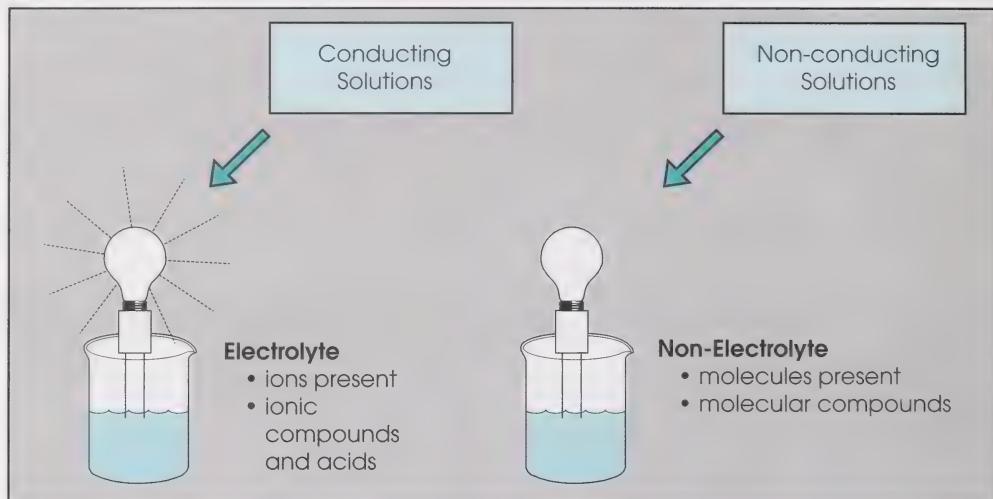
ACTIVITY

2 Dissociation

Why is it dangerous to have electrical appliances in a bathtub full of water? Is it a good idea to be out fishing in a boat during an electrical storm? Tap water and lake water are examples of conducting solutions.

In Section 1, you studied a theory which explains how compounds dissolve to form conducting solutions. Answer the following review questions on solution conductivity.

1. What type of solutes are electrolytes?
2. What are the particles responsible for the conductivity of a solution?



Check your answers by turning to the Appendix, Section 3: Activity 2.

Previous to this activity, you have seen several methods of dealing with ions qualitatively.

To see that ions can be described quantitatively, do the following investigation.

Investigation: Comparing the Degrees of Conductivity of Two Solutions

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☐ F. Evaluating

Carefully follow the directions of this investigation. Pay special attention to the required components, safety aspects, and applied science skills.

Problem

Can you measure the different concentrations of ions using conductivity as a variable?

Materials

- conductivity tester
- 0.10 mol/L $\text{CH}_3\text{COOH}_{(\text{aq})}$
- 0.10 mol/L $\text{HCl}_{(\text{aq})}$
- spot plate
- eyedropper

Procedure

- Place about 15 drops of each solution in separate spots on a spot plate.
- Test the degree of conductivity of the two solutions with a conductivity tester.

Evidence

- Complete the evidence for this investigation by filling in a chart similar to the following.

Solution	Degree of Conductivity
$\text{CH}_3\text{COOH}_{(\text{aq})}$	
$\text{HCl}_{(\text{aq})}$	

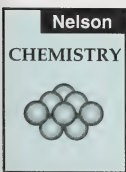
Analysis

- Which solution contains the strongest electrolyte?
- According to Arrhenius, what would explain the differences in the conductivity of the two solutions?
- The process that acidic compounds undergo when they dissolve to form conducting solutions is _____.

Since there are more ions formed from the ionization of $\text{HCl}_{(\text{aq})}$ than $\text{CH}_3\text{COOH}_{(\text{aq})}$, the hydrochloric acid solution conducts to a greater degree.

- Given the results from the preceding investigation, which ionic compound would give a greater concentration of ions in solution and therefore a greater conductivity, $0.10 \text{ mol/L CaCl}_{2(\text{aq})}$ or $0.10 \text{ mol/L NaCl}_{(\text{aq})}$?

Check your answers by turning to the Appendix, Section 3: Activity 2.

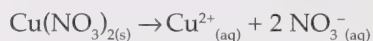


It is often hard to understand exactly what happens when a substance dissociates in solution. For a brief review of the solution process, read the two paragraphs on pages 115 and 116 of your textbook and study the diagrams. It is important for you to understand the process described because it applies to several topics that you will study in this course.

How do you represent on paper what happens in the solution process?

dissociation equation – an equation that shows a solute separating into its ions – it is balanced and the net charge of the ions is zero

Dissociation equations are written to show the separation of a compound into its ions. The following dissociations are for sodium hydroxide and copper(II) nitrate:



The equations show you that one mole (unit of amount) of sodium hydroxide forms two moles of ions – one mole of sodium ions and one mole of hydroxide ions. One mole of copper(II) nitrate separates to form three moles of ions – one mole of copper ions and two moles of nitrate ions.

8. What is the net charge of the ions formed by a dissociating compound?

Dissociation equations are written for soluble ionic compounds and for acids. It is important to write the formula for each ion correctly.

9. In the following table, classify the compounds as soluble or low solubility. Then write dissociation equations for the soluble compounds. If the compound has low solubility then there is no need for a dissociation equation. Low solubility compounds do not dissociate readily in water.

Solute	Solubility	Dissociation Equation
HClO_4		
K_2SO_4		
$\text{Ca}_3(\text{PO}_4)_2$		
NaBr		
$\text{Pb}(\text{NO}_3)_2$		
BaSO_4		
MgCl_2		

Check your answers by turning to the Appendix, Section 3: Activity 2.

The concentrations of the ions in a solution can be described using molar concentration. An analogy of money in a bank can be used to show why the concentration of ions is greater than the concentration of the solute which forms them. Look at the two banks in the following graphic.

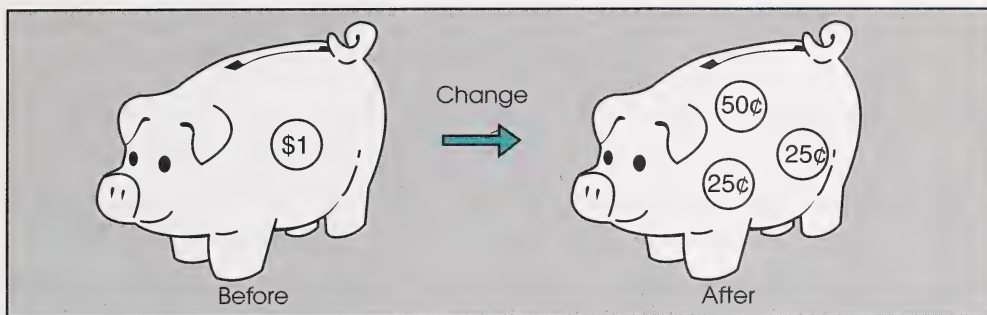


FIGURE 1.14: Piggy Bank Analogy

Figure 1.14 shows that a one-dollar coin has been changed into three coins. The concentration of the money can be described in terms of particles per bank.

10. Refer to Figure 1.14 to fill in the blanks about the concentration of the money in the bank.

The concentration of the dollar coin is _____ particle per bank. The dollar coin can be changed into a total of _____ particles. The concentration of the 50¢ coin is _____ particle per bank and the concentration of the quarters is _____ particles per bank.

Check your answers by turning to the Appendix, Section 3: Activity 2.

You can compare this situation to the dissociation of barium chloride. The following figure shows a formula unit of barium chloride dissociating into a barium ion and chloride ions.

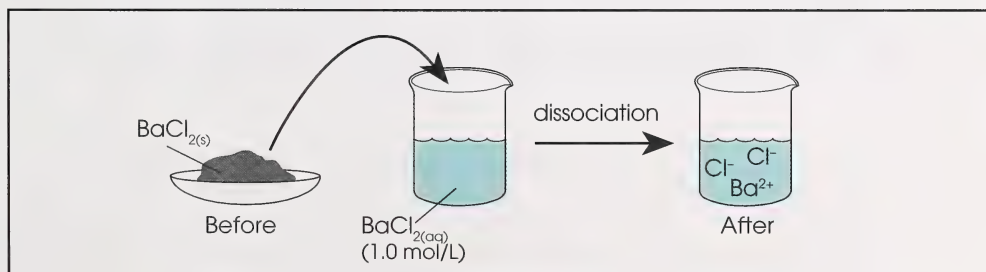


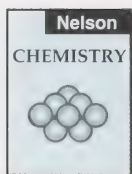
FIGURE 1.15: Barium Chloride Dissolving

11. Use Figures 1.14 and 1.15 to fill in the required information in the following comparison of the concentration of ions in the solution and the number of coins in the piggy bank.

The concentration of the barium chloride solution is _____ mol/L. After the formula unit dissociates, the concentration of $\text{Ba}^{2+}_{(\text{aq})}$ is _____ mol/L and the concentration of $\text{Cl}^{-}_{(\text{aq})}$ is _____ mol/L. You can compare the dollar coin in the bank example to the _____ in the solution example. Changing the dollar coin can be compared to _____ the barium chloride. In the bank example, there were _____ coins produced. In the solution example there were _____ moles of ions formed.

Check your answers by turning to the Appendix, Section 3: Activity 2.

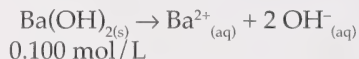
You will find that it is often important to know the concentration of ions and other substances in solution. For example, the concentration of chlorine in chlorinated drinking water must be monitored very closely so that the chlorine does not reach toxic levels.



Review the idea of ion concentration and read the examples in the section Concentration of Ions on page 129 of *Nelson Chemistry*. Then answer the questions which follow.

12. Complete questions 21 (a, b, c) and 22 (a, b, c) from page 131 of your textbook.

Showing the calculation of the concentration of ions is straightforward. For example, if the solute, $\text{Ba}(\text{OH})_{2(\text{aq})}$, has a concentration of 0.100 mol/L, the dissociation can be written like this:



The concentration of ([]) the $\text{Ba}^{2+}_{(\text{aq})}$ and OH^{-} ions is shown as follows:

$$[\text{Ba}^{2+}_{(\text{aq})}] = 1 \times 0.100 \text{ mol/L} = 0.100 \text{ mol/L}$$

$$[\text{OH}^{-}_{(\text{aq})}] = 2 \times 0.100 \text{ mol/L} = 0.200 \text{ mol/L}$$

The coefficients (numbers in front of the chemical formula) are used to calculate the concentration of the ion. When doing problems involving the concentration of ions in a solution, you may have to calculate the concentration of the solute first; then calculate the concentration of the ions. The next three questions involve calculating the concentration of the solute first.

13. What is the concentration of the cations and anions when 0.371 mol of $\text{Na}_3\text{PO}_{4(s)}$ is dissolved to make 250 mL of solution?
14. What is the concentration of the cations and anions when 2.08 g of barium chloride is dissolved to make 100 mL of $\text{BaCl}_{2(aq)}$?
15. What is the concentration of the dichromate ions in a solution made by dissolving 5.50 g of $\text{K}_2\text{Cr}_2\text{O}_{7(s)}$ to make a 2.50 L solution?

Check your answers by turning to the Appendix, Section 3: Activity 2.

You have learned how soluble ionic compounds dissociate and how to describe their concentration in units of mol/L. In the next activity you will learn how these ions interact in a **saturated solution**. How can you tell what ions do in solution if you can't see them?

saturated solution – a solution containing the maximum amount of dissolved solute at its temperature

ACTIVITY

3

Equilibrium



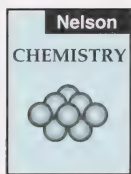
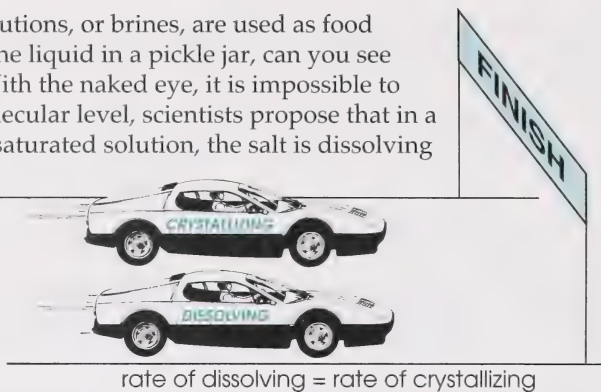
Do you take sugar in your tea? Do you like your tea very sweet? After you drink some of the tea and it has cooled down, you may find that some of the sugar has crystallized on the bottom of the cup. The remaining tea is now a saturated solution.

crystallizing – forming of a solid from its ions or molecule

Solutes like sugar dissolve and crystallize. These two processes are opposites. Sometimes they happen at the same time and at other times, one is happening very rapidly compared to the other. For example, dissolving happens when the sugar is first added to the tea. There is very little sugar **crystallizing** at this point. Crystallizing would happen if most of the tea is consumed and the remainder cools down.

Saturated sodium chloride solutions, or brines, are used as food preservatives. If you look at the liquid in a pickle jar, can you see crystallizing or dissolving? With the naked eye, it is impossible to notice any change. At the molecular level, scientists propose that in a sealed pickle jar containing a saturated solution, the salt is dissolving and crystallizing at the same speed so you cannot detect a change occurring.

Imagine that you and a partner are given two 20 L pails. Each time one of you removes a pailful of water from a pool, the other pours a pailful into the pool. There would not be a noticeable change in the water level of the pool. The speed of filling the pool would balance the speed of emptying it.



dynamic – happening all the time; never-ceasing

rate – the speed of a reaction or change

equilibrium – a system that has constant properties because its two opposing processes are occurring at equal rates

To learn the vocabulary involved in describing what is happening in a saturated solution, read the section Solubility Equilibrium on page 137 of your textbook. Use this information and the following figure to answer the questions that follow.

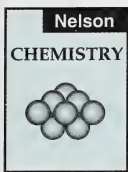
1. Place the following words in the appropriate blanks in the paragraph.

- | | | |
|---------------|--------------|-------------------|
| • balance | • closed | • dynamic |
| • equilibrium | • opposite | • rate |
| • overall | • saturated | • crystallization |
| • equal | • dissolving | • motion |



The clown juggling the balls is a system at **equilibrium**. The system is a _____ system since there are no balls entering or leaving. There is a _____ since the two opposing forces happen at the same _____.

One force is the ball being thrown by the clown, the other is the ball being caught by the clown. Because these two processes are _____ and happen at the same speed, an _____ exists. It is a _____ equilibrium because the balls are always in _____. The juggling of the balls is analogous to what happens in a _____ solution. If the ball leaving the clown's hand is compared to the dissolving of a solute, then the clown catching the ball is like _____. There is a dynamic equilibrium that exists in a saturated solution since the rate of _____ is equal to the rate of crystallizing. When you observe the solution, you see no _____ change.

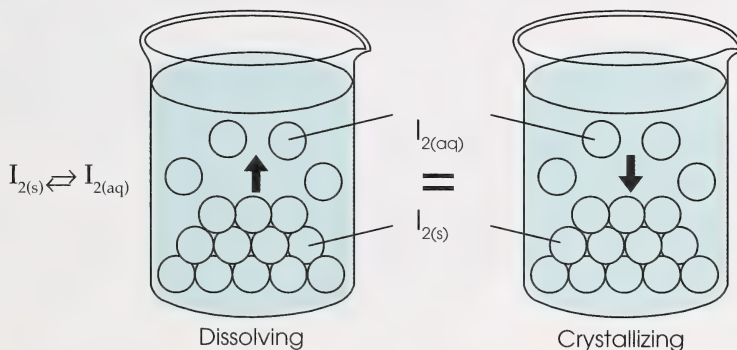


How can the action of the molecules and ions in a solution be verified? Read Testing the Theory of Dynamic Equilibrium on pages 137 and 138 of the textbook to find out two ways this explanation can be illustrated. Then answer the questions that follow.

2. One test of _____ is to shake a jar of _____ every day for two weeks. The amount of solute is _____ but the shapes of the particles change. This shows that the rates of _____ and _____ are equal. A second test involves the addition of radioactive iodine _____ and a saturated solution to test tubes containing a saturated solution. The radioactive iodine is _____ throughout the mixture. It is found in the crystals and in the solution. This shows that the _____ of dissolving and crystallizing are _____. It also shows that these two _____ happen all the time.

A system in equilibrium is symbolized by an equation that has double arrows instead of a single one. The arrows represent the processes that are happening at the same rate.

For example, the saturated iodine solution at equilibrium is written as:



Iodine is a molecular compound. It does not dissociate. Saturated ionic compounds can also be shown in equilibrium. Brine solution could be shown as the following:



Note the similarities between an equation showing equilibrium and a dissociation equation. The only difference is the double arrows in the equilibrium equation.

Now that you have learned how to write an equation for an equilibrium system, do the following question.

3. Fill in the following chart. Classify each solute as an electrolyte or a non-electrolyte. Then write the equilibrium equation for the saturated solution.

Solute	Electrolyte?	Equilibrium Equation
Limestone, $\text{CaCO}_{3(s)}$		
Sugar, $\text{C}_{12}\text{H}_{22}\text{O}_{11(s)}$		
$\text{Na}_3\text{PO}_{4(s)}$		
$\text{CuSO}_{4(s)}$		
$\text{CO}_{2(g)}$		

Check your answers by turning to the Appendix, Section 3: Activity 3.

If you look carefully, you can find examples of equilibrium everywhere – the dancer who pirouettes without falling; the fountain in the park that continually runs without losing or gaining water; the running river in winter that shows ice chunks floating in liquid water. These all have a balance in common with the solution equilibria you have been studying.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

A solubility chart can be used to find out the following:

- if solutions will form a precipitate when mixed together
- if ions in one solution will form a solid and the other ions will remain in solution (selective precipitation)
- how soluble a compound is if the concentration of solute is 0.100 mol/L
- the state of an ionic compound if a solution has reacted

- Which of the following mixtures would result in the formation of a precipitate?
 - $\text{AgNO}_{3(aq)}$ and $\text{K}_2\text{S}_{(aq)}$
 - $\text{BaCl}_{2(aq)}$ and $\text{NaOH}_{(aq)}$
 - $\text{NaCH}_3\text{COO}_{(aq)}$ and $\text{Sr}(\text{OH})_{2(aq)}$ and $\text{Na}_2\text{SO}_{4(aq)}$
 - $\text{Ti}^+_{(aq)}$ and $\text{NaCl}_{(aq)}$
 - $\text{SO}_4^{2-}_{(aq)}$ and $\text{MgCl}_{2(aq)}$
- Write balanced equations for the following mixtures. Make sure that the states of the substances are indicated.
 - Lead(II) nitrate solution is tested with a few drops of sodium chloride.
 - Calcium nitrate solution is tested with a solution of sodium sulphate.
- Classify the following solutes as soluble or low solubility. Write a dissociation equation for the appropriate solutes.

Solute	Solubility	Dissociation Equation
$\text{Cu}(\text{NO}_3)_2$		
PbSO_4		
$\text{Ba}(\text{OH})_2$		
$\text{K}_2\text{Cr}_2\text{O}_7$		

- List an ion that would form a precipitate with the following solutions.
 - $\text{Na}_2\text{S}_{(aq)}$
 - $\text{CuSO}_{4(aq)}$
 - $\text{SrBr}_{2(aq)}$
 - $\text{KI}_{(aq)}$
- Supply the missing information in the following chart.

Solute Concentration	Solute	[cations] (mol/L)	[anions] (mol/L)
3.0 mol/L	$\text{NaCl}_{(aq)}$		
6.0 mol/L	$\text{HCl}_{(aq)}$		
0.100 mol/L	$\text{Pb}(\text{NO}_3)_{2(aq)}$		
0.500 mol/L	$\text{Na}_3\text{PO}_{4(aq)}$		

A system is in equilibrium if

- it is closed
 - there are two processes happening at the same rate
 - the two processes are opposites
6. To make a saturated solution, 20 g of $\text{Na}_3\text{PO}_{4(s)}$ were mixed with water to make 50.0 mL of solution.
- Would you see anything happening in the beaker after this was done?
 - After 24 h, is there any dissolving happening?
 - Is there any crystallizing occurring after 24 h?
 - Write a balanced equation showing this equilibrium.
 - Calculate the concentration of each ion in solution.

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

Do any **one** of the following.

- Perform the following investigation if you have access to laboratory facilities.

Investigation: The Silicate Garden

Purpose

To investigate some aspects of equilibrium and precipitation.

Materials

- water glass [sodium thiosulphate solution ($\text{Na}_2\text{S}_2\text{O}_{3(aq)}$)]
- iron(III) chloride (FeCl_3) crystals
- copper(II) chloride (CuCl_2) crystals
- cobalt(II) nitrate [$\text{Co}(\text{NO}_3)_2$] crystals
- zinc sulphate (ZnSO_4) crystals
- 250 mL beaker
- distilled water
- scoopula

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Procedure

- Dilute 50 mL water glass with 200 mL distilled water in a beaker.
- Drop two or three crystals of each compound into the beaker.

Answer the following questions based on the observations of the investigation.

- What happens when each of the crystals is added to the water glass?
- Why do the compounds form the solids?
- List three compounds that would have no effect on the solution.

scale – a white crust formed when hard water is continually used

- Research the similarities between the **scale** that forms on your tea kettle and the stalactites and stalagmites that form in caves. What substance has the low solubility? How are the scale, stalactites, and stalagmites formed? Is there a chemical reaction involved or an equilibrium equation?
- Perform the following test for water hardness.

Science Skills

- ☐ A. Initiating
- ☒ B. Collecting
- ☒ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Background: Liquid soap can be used for a test of hardness of water. If soap lathers easily then it contains few mineral ions. If it does not lather, then it is “**hard**” water. Soap (not detergent) will precipitate the calcium ions that make the water “hard.”

Materials

- rainwater (or melted snow)
- drinking water
- boiled drinking water
- other samples of water you may have available
- liquid soap

Procedure

- Take 50 mL (1/4 cup) of rainwater and put it into a beaker.
- Add liquid soap drop by drop and shake the solution. If it lathers for 30 s, then stop adding the drops.
- Record the number of drops you need.
- Repeat the steps with the other water samples.

- Prepare and complete a data table for your evidence.
- Write an analysis of your water samples.

Check your answers by turning to the Appendix, Section 3: Enrichment.

hard water – water which has a high concentration of calcium and magnesium compounds

Conclusion

In this section, you have had a brief glimpse into the unseen world of solutions. You have learned that compounds can dissolve to various degrees. This allowed you to identify the ions present in the solution. You have written dissociation equations for soluble compounds and have expressed the concentrations of ions. The theory of dynamic equilibrium has explained how these ions continually interact to form precipitates and how solids continuously dissolve in water.

Assignment
Booklet

ASSIGNMENT

Turn to Assignment Booklet 1B and do the assignment for Section 3.

MODULE SUMMARY

This module has begun your enhancement of science skills through the discussion of solution chemistry. Learning the various methods to describe solutions should enable you to make informed decisions on the dangers of some substances in the environment. The knowledge you gained may now allow you to answer the initial question: Would you take a drink from that mountain stream?

Appendix



Glossary

Science Skills

**Suggested
Answers**

Glossary

alloy: a solution made up metallic substances; a uniform mixture of metals

amphipods: small or microscopic crustaceans

anion: a negatively-charged particle

aqueous: dissolved in water

Arrhenius: scientist who proposed a theory to explain why some solutions conduct electricity

benefits: factors that are helpful or promote well-being

biomagnification: accumulation of substance in the consumers of a food chain

cation: a positively-charged particle

chaining: putting all operations together in one line

compound: a pure substance composed of a combination of two or more atoms

concentrated solution: the solution that has the greatest amount of dissolved solute compared to another solution of the same kind

concentration: the amount of substance dissolved per volume of solution

corrosive: anything that causes tissue damage or burns

crystallizing: forming of a solid from its ions or molecule

DDT: dichlorodiphenyltrichloroethane; pesticide that acts on the stomach of insects

dilute solution: the solution that has a relatively small amount of dissolved solute when compared to a solution of the same kind

dissociated: separated into positive and negative ions when an ionic compound is dissolved

dissociation equation: an equation that shows a solute separating into its ions – it is balanced and the net charge of the ions is zero

dissolve: mix two or more substances to form a solution

dynamic: happening all the time; never-ceasing

electrolyte: a solute that causes an aqueous solution to conduct electricity

element: a pure substance composed of only one kind of atom

equilibrium: a system that has constant properties because its two opposing processes are occurring at equal rates

flame test: a diagnostic tool which identifies the ions present in solution by the colour of flame they produce

food chain: a sequencing of organisms on the basis of energy transfer or who eats whom

fume hood: a cabinet that protects people because it draws out the air by using an exhaust system

hard water: water which has a high concentration of calcium and magnesium compounds

heavy metals: metallic elements that have a high density

herbicides: chemicals that kill plants

heterogeneous mixture: a mixture that has two or more parts that can be distinguished from one another; two or more components dissolved to form a uniform substance

homogeneous mixture: a mixture that has two or more parts that cannot be distinguished from one another; two or more components dissolved to form a uniform substance	rate: the speed of a reaction or change
ionic: a substance that is composed of positive and negative ions	risks: dangerous elements or factors
ions: particles formed from atoms or molecules that have a charge	saturated solution: a solution containing the maximum amount of dissolved solute at its temperature
larvae: juvenile form of insects	scale: a white crust formed when hard water is continually used
minerals: relatively pure metal compounds	science skills: processes and their component skills required to obtain a solution to a particular problem
molar concentration: the number of moles of solute dissolved per one litre of solution	selectively precipitate: precipitate one ion of choice while leaving other ions in solution
molar mass: the number of grams of a substance needed to make one mole	solubility: how well a substance dissolves
non-electrolyte: a solute that does not cause an aqueous solution to conduct electricity	solute: the dissolved substance in a solution that is present in the smallest amount
PCB: polychlorinated biphenyl; organic toxic substance once commonly used, used currently as electrical transformer fluid	solvent: the dissolved substance in a solution that is present in the greatest amount
pesticides: chemicals that kill organisms which compete with man for food or destroy stored food	state: the phase of the substance
plasma: the liquid portion of blood that remains after the cells have been removed	strong electrolyte: a substance that forms a highly conductive solution
precipitate: a solid formed during the reaction of two solutions	systems: sets of things or parts forming a whole; integrated components working together
qualitative: observations of what is present, made without measurements	toxic: poisonous or harmful
qualitative analysis: using diagnostic tests to find out what substances are present	weak electrolyte: a substance that forms a poorly conductive solution
quantitative: observations of what is present, made with measurements	[]: abbreviation for concentration of anything in the closed brackets

Science Skills

A. Initiating and Planning

- identify and clearly state the problem or issue to be investigated
- differentiate between relevant and irrelevant data or information
- assemble and record background information
- identify all variables and controls
- identify materials and apparatus required
- formulate questions, hypotheses and/or predictions to guide research
- design and/or describe a plan for research or to solve the problem
- prepare required observation charts or diagrams

B. Collecting and Recording

- carry out and modify the procedure if necessary
- organize and correctly use apparatus and materials to collect reliable experimental data
- accurately observe, gather, and record information or data according to safety regulations (e.g., WHMIS) and environmental considerations

C. Organizing and Communicating

- organize and present data in a concise and effective form (themes, groups, tables, graphs, flow charts, and Venn diagrams)
- communicate data more effectively, using mathematical and statistical calculations where necessary
- express measured and calculated quantities to the appropriate number of significant digits and use appropriate SI units for all quantities

D. Analysing

- analyse data and information for trends, patterns, relationships, reliability, and accuracy
- identify and discuss sources of error and their effect on results
- identify assumptions, attributes, bias, claims, or reasons
- identify main ideas

E. Connecting, Synthesizing, and Integrating

- predict from data or information
- formulate further testable hypotheses supported by the knowledge and understanding generated
- identify alternatives for consideration
- propose and explain interpretations or conclusions
- develop theoretical explanations
- relate the data to laws, principles, models, or theories identified in background information
- answer the problem investigated
- summarize and communicate finding
- decide on a course of action

F. Evaluating the Process or Outcomes

- establish criteria to judge data or information
- consider consequences and perspectives
- identify limitation of the data and information, interpretations, or conclusions as a result of the experimental / research / project / design, processes, or methods used
- suggest alternatives and consider improvements to experimental technique and design
- evaluate and assess ideas, information, and alternatives

CRITERIA FOR ASSESSING SCIENTIFIC PROBLEM-SOLVING SKILLS

A. INITIATING AND PLANNING

Level 1	Level 2	Level 3	Level 4	Level 5
Proposes a simple problem statement when initiated to do so	Proposes a simple problem statement	Proposes a problem to be investigated	Clearly states the purposes and problem to be investigated	Performs at a level beyond level 4
Background information must be supplied	Background information is supplied from teacher or student's own experience	Background supplied by teacher, reference material, or student's own experience	Prepares the necessary background information from references, research, discussion, and/or past experience	Characteristic of work done at college or university level
Identifies those things that change and those that stay the same	Identifies variables and controls	Identifies controls, manipulated variables, and responding variables	Identifies the controls and variables	
Guesses about the outcomes	Makes 'educated' guesses	Makes a prediction and/or suggests a simple hypothesis	- Forms an appropriate hypothesis and prediction - Designs an investigation	
Identifies simple materials and equipment to be used	- Identifies materials and equipment to be used - Is able to assemble simple apparatus	- Identifies the materials and equipment to be used - Assembles simple apparatus	- Identifies and names the materials and equipment to be used - Assembles and designs or modifies simple apparatus	
Follows directions as provided	- Follows directions as provided - Is able to write simple procedural statements	Develops and organizes a simple written procedure	Designs and writes descriptions of procedures that are clear and detailed	
	Prepares observation charts, tables, and diagrams as directed by teacher	- Prepares observation charts, tables, diagrams, graphs - Performs calculations as outlined by teacher	- Prepares observation charts, diagrams, and graphs - Performs necessary calculations	

B. COLLECTING AND RECORDING

Level 1	Level 2	Level 3	Level 4	Level 5
Follows a simple procedure	Follows a simple procedure	Follows a given procedure and is able to suggest modifications when asked to do so	Follows a given procedure and modifies the procedure when necessary	Performs at a level beyond level 4
Correctly uses apparatus and materials as directed by teacher	Correctly uses apparatus and materials with little teacher assistance	Correctly uses apparatus and materials with infrequent modification	Consistently uses standard apparatus and materials correctly	Characteristic of work done at college or university level
Collects data using concrete, tangible objects	- Collects tangible objects - Carries out simple measurements	Accurately collects data	Accurately collects relevant data	
Records data in sentence form or in simple charts that have been constructed	- Records data in numerical and non-numerical form - Is able to use and construct simple charts	Records relevant data including the correct units with respect to measured data	Records relevant data using the appropriate units	
- Is aware of safety and environmental concerns - Follows stated safety procedures	- Is aware of safety and environmental concerns - Follows stated safety procedures	Shows appropriate safety and environmental concerns in the use, care, and maintenance of materials and apparatus	Demonstrates appropriate standards of safety	
		- Is able to locate appropriate safety regulations - Actively participates in teacher-directed discussion of safety and environmental issues	Is able to suggest modifications to procedures to minimize environmental damage	

C. ORGANIZING AND COMMUNICATING

Level 1	Level 2	Level 3	Level 4	Level 5
Organizes data in sets of concrete objects	Organizes data in sets of objects	Organizes data in the form of sets, themes, and/or tables	Organizes data accurately	Performs at a level beyond level 4
	- Provides a basis for the organization of data sets - Constructs simple graphs to represent the data	- Provides a basis for and suggests alternatives for the organization of data - Is able to construct graphs and/or tables to represent the data	Is able to represent data using appropriate graphs and tables	Characteristic of work done at college or university level
	Performs basic mathematical calculations	Performs basic mathematical calculations	Performs relevant and required mathematical calculations	
	Identifies, with teacher assistance, errors and inaccuracies	- Identifies errors and discrepancies in data - Takes part in teacher-directed discussion of scientific inaccuracies	Expresses measured and calculated quantities to correct degree of precision	

D. ANALYSING

Level 1	Level 2	Level 3	Level 4	Level 5
Correctly identifies patterns within the data	Assesses patterns and trends that are conceptually presented by the data	Assesses patterns, trends, and simple relationships	Assesses patterns, trends, and relationships resulting from collected and manipulated data	Performs at a level beyond level 4
Identifies, with teacher assistance, relationships	Identifies simple cause and effect relationships	Identifies cause and effect relationships	Identifies the sources of error in data collection and manipulation	Characteristic of work done at college or university level
	Identifies, with teacher assistance, the sources of error in data collection and manipulation	Identifies the sources of error in data collection and manipulation	- Expresses accuracy qualitatively and/or quantitatively (percent difference), where applicable - Identifies the assumptions relating to measurement and/or analysis	
	Identifies, with teacher assistance, the effect of errors on results	Suggests amendments to procedures and/or data manipulation in order to rectify results	Determines the reliability of the data	

E. CONNECTING, SYNTHESIZING, AND INTEGRATING

Level 1	Level 2	Level 3	Level 4	Level 5
Provides a simple but not necessarily appropriate answer to the problem investigated based on results obtained	Provides a simple answer that is appropriate for the problem investigated and results obtained	Provides an appropriate answer to the problem investigated based on results obtained	Provides a qualified answer to the problem investigated	Performs at a level beyond level 4
	Attempts to relate results to knowledge that is not specifically related to scientific theories or laws	Relates results, with teacher assistance, to applicable theories and/or laws	Relates the data to laws, principles, models, or theories identified in background information and/or in broader context	Characteristic of work done at college or university level
			- Proposes and explains interpretations or conclusions - Develops theoretical explanations	

F. EVALUATING THE PROCESS OR OUTCOMES

Level 1	Level 2	Level 3	Level 4	Level 5
Attempts to explain results to the problem investigated	Attempts to explain results to the problem investigated	Is able to explain the results obtained in light of the problem being investigated	Evaluates the prediction and concepts	Restricts, revises, or replaces an unacceptable scientific concept
	Attempts to draw conclusions where applicable and when prompted	Draws conclusions and attempts to explain them	Draws conclusions and attempts to explain them	Establishes criteria to judge the design, prediction, and concepts
		Discusses the limitations of the data collected, interpretations, and/or conclusions	Identifies limitations of the data and information, interpretations, or conclusions, as a result of the design of the experiment, research, or project	- Considers consequences and perspectives - Evaluates assumptions and effects of bias
		- Discusses, when prompted, the validity of results - Discusses, when prompted, alternatives and/or improvements to the experimental design	Suggests alternatives and considers improvements to experimental technique and design	Evaluates the total investigation in terms of reliability and validity

Science Skills Spreadsheet

You may reproduce this spreadsheet as required for use in this course.

CHARTING GROWTH IN SCIENCE SKILLS															
Feedback From Assignments			Initiating and Planning		Collecting and Recording		Organizing and Communicating		Analysing		Synthesizing and Integrating		Evaluating		
Module	Section	Question	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	
1	1	4													
	1	6													
	2	6													
	3	7													
2	1	11													
	2	17													
	2	18													
3	1	8													
	2	7													
4	1	1													
	1	2													
	2	3													
	3	1													
5	1	1													
	2	5													
6	1	2													
7	2	10													

Suggested Answers

Section 1: Activity 1

1. Scientists pose questions, make predictions or hypotheses based on scientific principles, and design and perform experiments to obtain answers to their questions.
2. Scientists evaluate their process by comparing their experimental results to the results they predicted.
3. The purpose is a general statement which describes the general intent of the investigation. The problem is a specific question, based on the purpose, that you intend to answer. The problem usually mentions the manipulated variable – the variable set by experimenter that is being studied, and the responding variable – the resulting outcome, as part of the question posed.
4. The experimental design states the general process by which the problem will be solved. The procedure outlines specific steps and measurements followed in solving the problem. The design often outlines the variables to be manipulated and controlled, as well as the responding variable.
5. Evidence gathered is empirically-based on the senses. There are no inferences or conclusions made. The analysis, however, does make inferences for explaining observations, making connections, etc.
6. The steps to be performed are indicated by check marks.
7. Three possible evidence tables are given with possible assessments.

EXAMPLE EVIDENCE TABLE 1

Substance	Observations
aluminum foil	The silver solid turned red when put into the beaker. Rust was formed.
copper chloride solution	The blue solution bubbled when the foil was put in.

Assessment Comments:

- The observations are organized in a table, which is good.
- The copper chloride name is not correct – it should be copper(II) chloride.
- There are not any observations specified before and after the reaction takes place.
- There are no quantitative observations.
- There is an inference in the table that rust was formed. This is not an observation.

Assessment:

Collecting and recording – level **2**

Organizing and communicating – level **2**

EXAMPLE EVIDENCE TABLE 2

Substance	Observations
aluminum foil	Before the reaction the 10 cm × 10 cm foil was silvery in colour.
copper(II) chloride	Before the reaction the copper(II) chloride was a blue solid weighing 5 g.
water	The water was a clear liquid before the reaction.
aluminum foil in solution	The aluminum foil started to smoke when it was placed in the solution. A reddish-brown solid appeared on the foil's surface.
copper(II) chloride solution	When the foil was added, the solution started to bubble around the edges of the foil and steam rose up.

Assessment Comments:

- Observations are more complete; there are some quantitative observations, but not many.
- The table is more organized with “before” and “after” observations.
- Terms are used correctly.

Assessment:

Collecting and recording – level **3**Organizing and communicating – level **3****EXAMPLE EVIDENCE TABLE 3**

Before Reaction:

Substance	Observations	
	Quantitative	Qualitative
aluminum foil	10 cm × 10 cm 0.5 g	silvery solid, shiny in appearance
copper(II) chloride	5 g (5 mL or 1 tsp.)	blue granular solid, dull appearance; when placed in water – initially was green but when dissolved, turned blue
water	23.5°C 100 mL	clear, colourless liquid

After placing the aluminum foil into the solution:

Substance	Observations
aluminum foil	10 s – aluminum foil appeared to be releasing steam when mixed in the $\text{CuCl}_2(\text{aq})$ 20 s – small patches of reddish-orange solid appeared on the surface – some small patches of black solid 50 s – surface of foil almost entirely covered with red solid – still a few patches of black and silver colour
copper(II) chloride solution	10 s – some steam starting to appear to rise from solution; some bubbles 20 s – more bubbling of solution around edges of foil; temperature has risen to 25.5°C 250 s – fairly vigorous bubbling around the edges of foil; solution has increased to 41.8°C

Assessment Comments:

- The table gives a very complete description of events.
- There are many examples of qualitative and quantitative observations.
- Descriptions are very clear.
- The table is well-organized.

Assessment:

Collecting and recording – level **4** Organizing and communicating – level **4**

- The reaction is exothermic because the temperature on the thermometer went up (increased). This shows that heat was released to the surroundings.
- The orange-red solid was solid copper.
- Evidence for a chemical change include a change in colour and the release of heat.
- Your assessments may vary. Teacher assessments for each example table are given under each evidence table in question 7.
- The skills will be practised within the student module booklet – in investigations, some analysis questions, etc.
 - The science skill icon in the left margin indicates when science skills are to be practised.
 - The skills focussed on are checked in the icon.
- The science skills assessment icon will be in the left margin of any questions where science skills are being assessed.
- The level assessment will not affect your grade. The purpose of the assessment is to help you improve in your self-assessment and to help you grow in your science skills.
- Complete information on the description of science skills is found in the Appendix of Module 1.
- You will gain positive feedback on your progress and growth throughout the course.
- You record your student assessment and the teacher assessment on the spreadsheet.
 - Using one spreadsheet gives you an idea of how much you have improved throughout the course. It also shows you areas in which you can improve.

Section 1: Activity 2

- The substances can be classified as follows:

a. a silver earring –	pure, element	e. gasoline –	mixture, homogeneous (solution)
b. ice –	pure, compound	f. table sugar –	pure, compound
c. concrete –	mixture, heterogeneous	g. pop –	mixture, heterogeneous
d. raisin cookie –	mixture, heterogeneous	h. vinegar –	mixture, homogeneous (solution)

2.

Solution	Component	Amount	Solute or Solvent?
Tooth Filling	mercury	50%	solvent
	silver	35%	solute
	tin	15%	solute
Air	argon	0.93%	solute
	carbon dioxide	0.03%	solute
	oxygen	20.9%	solute
	nitrogen	78.1%	solvent
	others	0.04%	solute
Steel	aluminum	1%	solute
	nickel	14%	solute
	iron	58%	solvent
	manganese	13%	solute
	chromium	14%	solute
Sea Water	chloride	1.898%	solute
	sodium ions	1.056%	solute
	magnesium ions	0.127%	solute
	sulphide	0.088%	solute
	calcium ions	0.040%	solute
	potassium ions	0.038%	solute
	bromide	0.065%	solute
	water	96.684%	solvent
	others	0.004%	solute

- The alloys are **steel** and **tooth filling**.
- The solution that is made up of solids and liquids is **a tooth filling**.
- The solution that is made up of gases is **air**.
- No, water is not always the solvent.
- The solute is not always a solid. The state of a substance doesn't determine whether it is a solute.
- No, the solute can be the same state as the solvent, for example, air has gaseous solutes.
- In Figure 1.4 Solution A is the concentrated solution, Solution B is dilute.
- The most concentrated solute in tooth fillings is **silver**.
- Of the gases listed, carbon dioxide has the lowest concentration.
- In sea water, the sodium ions are the second most concentrated ions.

13.

Substance	Degree of Conductivity
Distilled Water	does not conduct
Table Salt	does not conduct
Table Sugar	does not conduct
Salt Solution	low conductivity
Sugar Solution	does not conduct
Hydrochloric Acid	high conductivity

14. Water was tested as a control. This is so that comparisons can be made when the salt and sugar were dissolved in it.
15. Hydrochloric acid is the best conductor.
16. Water and sugar are molecular compounds. Salt is an ionic compound.
17. Ionic compounds and acids are electrolytes.
18. Molecular compounds are non-electrolytes.
19. Ions are formed when ionic compounds dissolve.
20. Ions allow a solution to carry a current of electricity.
21. The solutes may be classified as follows:
- $\text{Ca}(\text{NO}_3)_2$ **electrolyte**
 - $\text{C}_2\text{H}_5\text{OH}_{(l)}$ **non-electrolyte**
 - $\text{HBr}_{(aq)}$ **electrolyte**
 - KI **electrolyte**
 - NaHCO_3 **electrolyte**

Section 1: Activity 3

- The arrows show the direction that the ions move in the cycle.
 - The atmosphere is not really involved in the cycle because metal ions do not generally move into the atmosphere.
 - The amount of dissolved mineral can vary since the oceans do not return ions to the cycle. But the overall amount of minerals on a global scale remains constant.
- Some sources of electrolytes not shown in the diagram are the following: acid rain, fertilizers, sewage, herbicides, pesticides, drainage systems, and irrigation systems.

3. All ions are electrolytes. All the other substances in the table are molecular.

Name	Formula	Electrolyte or Non-electrolyte
Biocarbonate ions	$\text{HCO}_3^-_{(\text{aq})}$	electrolyte
Calcium ions	$\text{Ca}^{2+}_{(\text{aq})}$	electrolyte
Chloride ions	$\text{Cl}^-_{(\text{aq})}$	electrolyte
Fatty acids		non-electrolyte
Glucose	$\text{C}_6\text{H}_{12}\text{O}_{6(\text{aq})}$	non-electrolyte
Glycerol	$\text{C}_3\text{H}_5(\text{OH})_{3(\text{aq})}$	non-electrolyte
Oxygen	$\text{O}_{2(\text{aq})}$	non-electrolyte
Potassium ions	$\text{K}^+_{(\text{aq})}$	electrolyte
Proteins		non-electrolyte
Sodium ions	$\text{Na}^+_{(\text{aq})}$	electrolyte
Sulphate ions	$\text{SO}_4^{2-}_{(\text{aq})}$	electrolyte
Urea	$\text{CO}(\text{NH}_2)_{2(\text{aq})}$	non-electrolyte

4. According to Arrhenius, molecular compounds separate into individual molecules in the water. The molecules are then surrounded by the water.
5. When an ionic compound dissolves in water, the electrolyte dissociates into ions and then water molecules surround the ions.
6. Water molecules completely surround the molecules or ions during the dissolving process.
7. a. Solute **B** will create the greatest number of particles.
 b. Solution **B** has the greatest concentration.
 c. Solute **B** has dissociated.
 d. Solute **A** has dissolved but not dissociated.
 e. Solution **B** would conduct electricity.
8. Ionization is the formation of ions from molecules or atoms.
9. Pure acids exist as molecules.
10. Acids separate into molecules and then react with the water (ionize) to form positive hydrogen ions and negative ions when they dissolve.
11. Ionization involves the formation of new ions whereas dissociation involves the separation of ions that already exist.

Section 1: Activity 4

- If you chose using the ammonia solution, there are many possible reasons.
 - It is much safer to use the solution since the ammonia gas is dangerous.
 - It is easier to apply the solution with the mop than it is to fan the gas.
 - You could control how much of the ammonia to use by diluting the solution with water.
- Solution systems are used instead of pure substances for the following reasons:
 - safer when handling and transporting
 - easier to react chemicals under aqueous conditions
 - more control over rates of reactions
- A solution system maximizes the amount of surface a solute can react with. A solid does not have this ability, even in a powdered form.
- Headache medication is packaged in tablet form for ease of transport and dosage control. It is dissolved so that the active ingredient reacts more quickly in the blood stream.
- Solid drain cleaner, toilet bowl cleaner, laundry detergent, antacid tablets, salt, baking powder, sugar, and baking soda are some substances bought as solids yet used when mixed with water.
- There are three kinds of designs that you may have thought of to successfully complete this investigation. Check the following table to see if your design is similar to any of the three listed. Each of the designs depends on the variable you decided to manipulate. The manipulated variables are: concentration, temperature, volume. This table also answers question 11 in Part B.

Note: The easiest method would probably involve manipulating only Solution A or Solution B in your investigation. The answers to this investigation are written with the manipulation of both solutions.

Manipulated Variable	Design
Concentration	Dilute Solution A while keeping the concentration of Solution B constant. Then dilute Solution B while keeping the concentration of Solution A constant.
Temperature	Adjust the temperatures of Solutions A and B to 5°C before mixing. Then increase the temperature of both solutions 5°C for each trial.
Volume	Adjust the volume of either Solution A or Solution B so that the total volume remains at 5.0 mL.

- The following is a possible list of materials based on the variable you manipulated.

Manipulated Variable	Materials
Concentration	test tubes, 10.0 mL graduated cylinders (or 10.00 mL graduated pipets), stopwatch, distilled water, test tube rack
Temperature	hot water bath, ice water bath, test tubes, 10.0 mL graduated cylinders (or 10.00 mL graduated pipets), stopwatch, test tube rack
Volume	test tubes, 10.0 mL graduated cylinders (or 10.00 mL graduated pipets), stopwatch, test tube rack

8. The following chart outlines possible procedures based on the variable you manipulated. This chart also answers question 13 in Part B.

Manipulated Variable	Procedure																				
Concentration	• Pour 2.5 mL of Solution B into each of five test tubes. • Add 2.5 mL of Solution A to the first test tube and time the reaction. • For the next four test tubes, add 0.5 mL, 1.0 mL, 1.5 mL, and 2.0 mL respectively of distilled water. • Then to the same four test tubes, add 2.0 mL, 1.5 mL, 1.0 mL, and 0.5 mL of Solution A, timing the reaction as you go along. • Pour 2.5 mL of Solution A into each of four clean test tubes. • Add 0.5 mL, 1.0 mL, 1.5 mL, and 2.0 mL respectively of distilled water to the test tubes. • Then to the same four test tubes, add 2.0 mL, 1.5 mL, 1.0 mL, and 0.5 mL of Solution B, timing the reaction as you go along.																				
Temperature	• Pour 2.5 mL of Solution A into a test tube. • Pour 2.5 mL of Solution B into a test tube. • Place the test tubes into a hot water bath until their temperature registers 5°C. • Mix the two solutions together and time the reaction. • Repeat the procedure increasing the temperature by 5°C increments until a temperature of 45°C is reached.																				
Volume	• To each of nine test tubes add the following amounts of Solution A:<table><tr><td>Test tube #</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr><tr><td>Volume of Solution A (mL)</td><td>0.50</td><td>1.00</td><td>1.50</td><td>2.00</td><td>2.50</td><td>3.00</td><td>3.50</td><td>4.00</td><td>4.50</td></tr></table> • React 4.5 mL of Solution B with the test tube containing 0.50 mL of Solution A and measure the reaction time. • React 4.0 mL of Solution B with the test tube containing 1.0 mL of Solution A and measure the reaction time. • Continue to react 0.5 mL-less increments of Solution B with the remaining test tubes of Solution A.	Test tube #	1	2	3	4	5	6	7	8	9	Volume of Solution A (mL)	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
Test tube #	1	2	3	4	5	6	7	8	9												
Volume of Solution A (mL)	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50												

9. The following charts may serve as evidence. The given results are idealized. When you are checking your results, see if the trends are the same. Copy one of the data tables if you are doing Part B.

MANIPULATING THE CONCENTRATION**The Effect of Diluting Solution A and Solution B on the Rate of the Reaction**

Test Tube	Volume of Distilled Water (mL)	Volume of Solution A (mL)	Volume of Solution B (mL)	Time (s)
1	0	2.5	2.5	10.0
2	0.5	2.0	2.5	17.3
3	1.0	1.5	2.5	25.2
4	1.5	1.0	2.5	30.6
5	2.0	0.5	2.5	41.7
6	0.5	2.5	2.0	8.3
7	1.0	2.5	1.5	4.6
8	1.5	2.5	1.0	3.2
9	2.0	2.5	0.5	0.6

MANIPULATING THE TEMPERATURE**The Effect of Changing the Temperature of the Reactant on the Rate of the Reaction**

Mixture	Temperature of Solution (°C)	Time (s)
1	5	52.8
2	10	30.1
3	15	18.3
4	20	10.0
5	25	9.3
6	30	6.2
7	35	4.3
8	40	0
9	45	0

MANIPULATING THE VOLUME**The Effect of Changing the Volume of the Reactants on the Rate of the Reaction**

Mixture	Volume of Solution A (mL)	Volume of Solution B (mL)	Time (s)
1	0.5	4.5	0.8
2	1.0	4.0	3.1
3	1.5	3.5	4.2
4	2.0	3.0	7.3
5	2.5	2.5	10.0
6	3.0	2.0	16.2
7	3.5	1.5	22.3
8	4.0	1.0	36.1
9	4.5	0.5	44.8

10. The following table will provide an analysis of the investigation. This table also answers question 15 in Part B.

Manipulated Variable	Analysis
Concentration	The closest timing for the iodine clock reaction was 25.2 s. The experimental design needs to be improved since this is not very close to 20.0 s. If there was more time, this problem could be solved by using scientific methods (or trial and error). However, since there is a limited amount of time, the procedures should be adjusted so that there is room to adjust and record the concentrations as you go along. The design is valid to find out how to speed up and slow down the reaction but after discovering this, it is easier to guess or approximate the concentrations.
Temperature	The closest timing for the iodine clock reaction was 18.3 s. This is not very close to the goal of 20.0 s. As with the concentration, the procedures should be adjusted so that there is room to adjust and record the temperatures as you go along. This would allow you to more quickly find a temperature that gives you a 20.0 s interval. It is also difficult to get both solutions to read the same temperature, so manipulating the temperature of only one solution would have worked better.
Volume	The closest timing for the iodine clock reaction was 22.3 s. The experimental design needs to be improved since this is not very close to 20.0 s. Again, the procedures should be adjusted so that there is room to adjust and record the volumes as you go along. Once the time is near 20.0 s, the volumes you need can be identified. The design is valid to find out how to speed up and slow down the reaction but after this it would probably be easier to adjust the volumes by estimating and guessing.

11. There are three kinds of designs that you may have thought of to successfully complete this investigation. Check the table in question 6, Section 1, Activity 4 to see if your design is similar to any of the three listed. Each of the designs depends on the variable you decided to manipulate. The manipulated variables are: concentration, temperature, volume.
12. The following is a possible list of materials based on the variable you manipulated.

Manipulated Variable	Materials
Concentration	test tubes, 10.0 mL graduated cylinders (or 10.00 mL graduated pipets), stopwatch, distilled water, test tube rack
Temperature	hot water bath, ice water bath, test tubes, 10.0 mL graduated cylinders (or 10.00 mL graduated pipets), stopwatch, test tube rack
Volume	test tubes, 10.0 mL graduated cylinders (or 10.00 mL graduated pipets), stopwatch, test tube rack

13. Refer to the chart given in question 8, Section 1, Activity 4. The chart outlines possible procedures based on the variable you manipulated.
14. Copy one of the given sample tables from question 9, Section 1, Activity 4. Choose the table that illustrates the variable you are manipulating.
15. Refer to the table given in question 10, Section 1, Activity 4. The table will provide an analysis of the investigation.

16. Textbook question 8:

- a. iron(III): **yellow-brown** c. $\text{Cu}^{2+}_{(\text{aq})}$: **blue**
 b. sodium: **colourless** d. $\text{Ni}^{2+}_{(\text{aq})}$: **green**

Textbook question 9:

- a. calcium: **yellow-red** c. Na^+ : **yellow**
 b. copper(II): **blue or green** d. K^+ : **violet**

17. The following may be an analysis of Lab Exercise 5C: Qualitative Analysis by Colour.

Solution 1 contains copper according to the flame test. The colour of the solution narrows it down to Cu^+ .

Solution 2 contains sodium according to the flame test. This matches with the colour in solution since sodium ions are colourless.

Solution 3 contains potassium ions since the flame test is violet. The solution colour purple means that MnO_4^- ions are also present. The solute is a combination of the two ions, K^+ and MnO_4^- , which give $\text{KMnO}_{4(\text{aq})}$.

Solution 4 contains copper ions according to the flame test. According to the ion colour, Cu^{2+} ions are present since the solution is blue.

Section 1: Follow-up Activities

Extra Help

1. This module examines a specific kind of **homogeneous** mixture called a solution. A solution is made up of two basic parts, a **solute** and a solvent. When you look at a solution, it is impossible to see the solute separately from the solvent because they are mixed together thoroughly. There is less **solute** than **solvent** and they are mixed together evenly. If a solution is **concentrated**, then it contains more solute when compared to another solution of the same kind. In an **aqueous** solution, the solvent is **water** and the solute could be an ionic compound, a molecular compound, or a dissolved acid. If the dissolved solute was a molecular compound, then it is classified as a **non-electrolyte** since it does not conduct electricity. If the solute is an **ionic** compound or an **acid** then it is classified as an electrolyte.

2.

Solution	Vinegar	Salted water	Gasoline	Lemon juice	Beer
Solute	acetic acid	sodium chloride	molecular liquids	citric acid	ethanol
Solvent	water	water	octane	water	water
Dissolves	✓	✓	✓	✓	✓
Dissociates	no	✓	no	no	no
Ionizes	✓	no	no	✓	no
Ions present	✓	✓	no	✓	no
Conducts	✓	✓	no	✓	no

- An example of a solution that is part of a living system is plasma. An example of a solution that is part of a non-living system is $\text{CuSO}_{4(aq)}$.
- Aqueous HCl is used more often than gaseous HCl for the following reasons:
 - ease of handling
 - easy to react
 - easy to manipulate reactions in solutions

5.

Solution	Colour Produced by Flame Test	Colour of Solution	Possible Identity of Ion Present
1	yellow	colourless	Na^+
2	green	colourless	Ba^{2+} (Zn^{2+})
3	green	blue	Cu^{2+}
4	yellow	orange	Na^+ and $\text{Cr}_2\text{O}_7^{2-}$

Enrichment

- Fireworks are explosives that contain additional substances, besides the explosive chemicals, to make the colours. Sodium nitrate, barium nitrate, copper(II) nitrate, and strontium nitrate are some of the substances you may have discovered that are used to make yellow, blue, green, and red. Sometimes fireworks contain powdered elements, such as carbon, zinc, or aluminum to make a sparkling trail.
- The chemical analysis of your water may not be an easy thing to find out. A water analysis may also have information about bacteria present. Bottled water has the contents listed on the label. For example, a listing may be in parts per million (ppm) and may have listed all the substances present.

Bottled Water Contents

Substance	ppm	Substance	ppm
Ca^{2+}	78.00	HCO_3^-	357.00
Mg^{2+}	24.00	SiO_2	13.00
K^+	1.00	Na^+	5.00
SO_4^{2-}	10.00	Cl^-	3.00
NO_3	1.00	F^-	0.12
Cu/Zn/Pb/As	0	Dissolved Minerals	3.00

pH = 7.2

Perhaps the greatest difference is how extensive the list of dissolved solutes is for your water compared to the bottled water. Another difference may be found if your water is "hard" – there may be more calcium and magnesium ions. If the pH is listed on your water analysis, it may be different than the one listed on the bottled water.

3. Some of the ingredient lists on insecticides may not be comprehensive. For example, one plant soap that is used as an insecticide is labelled as containing 50.5% potassium salts of fatty acids. This information is not very useful to know. The safety precautions, disposal information, and first aid directions are more important to know.

Fertilizers, on the other hand, give a comprehensive list of ingredients. For example, fertilizer for house plants may list the ingredients as follows:

Ammoniacal nitrogen	1.0%
Nitrate nitrogen	0.6%
Urea nitrogen	8.4%
Available phosphoric acid	15%
Soluble potash	10%
Sources: urea, ammonium and potassium phosphate, potassium nitrate	

Although this information is not as detailed as a water analysis is, it is useful for a grower to know. Combined with knowledge of plant requirements, you can make a decision on whether or not the fertilizer is the best one to use.

Section 2: Activity 1

1. A dark colour means concentrated; a light colour means dilute.
2. Molar concentration is defined as the moles of solute dissolved per litre of solution.
3.
 - a. The conversion factor converted the 25.0 mL into 0.0250 L.
 - b. The small *m* stands for *milli* or 0.001 of the base unit.
 - c. If a unit, such as *mL* in the example, is found on the top line and the bottom line of a calculation, then it can be divided out or cancelled.
4. The relationship used in the solution calculations may be given as follows: $C = \frac{n}{v}$.

5.

Symbol	Description	Units
C	molar concentration	mol/L
n	number of moles (amount)	mol
v	volume of solution	L

6.
 - a. $n = Cv$
 - b. $v = \frac{n}{C}$

7. The molar concentration of the solution may be calculated as follows:

List of Variables: $C = ?$ $n = 1.20 \text{ mol KNO}_3$ $v = 2.00 \text{ L}$	
Formula Method	Factor Label Method
$C = \frac{n}{v}$ $= 1.20 \text{ mol} / 2.00 \text{ L}$ $= 0.600 \text{ mol} / \text{L}$	$C = 1.20 \text{ mol} \times \frac{1}{2.00 \text{ L}}$ $= 0.600 \text{ mol} / \text{L}$

8. The amount of solute may be calculated as follows:

List of Variables: $n = ?$ $v = 0.200 \text{ L (from } 200 \text{ mL)}$ $C = 0.625 \text{ mol} / \text{L HCl}$	
Formula Method	Factor Label Method
$C = \frac{n}{v}$, therefore $n = Cv$ $n = 0.625 \text{ mol} / \text{L} \times 0.200 \text{ L}$ $= 0.125 \text{ mol}$	$n = \frac{0.625 \text{ mol}}{\cancel{\text{L}}} \times 0.200 \cancel{\text{L}}$ $= 0.125 \text{ mol}$

9. The volume of solution may be calculated as follows:

List of Variables: $v = ?$ $n = 0.0800 \text{ mol C}_6\text{H}_{12}\text{O}_6$ $C = 0.300 \text{ mol} / \text{L}$	
Formula Method	Factor Label Method
$C = \frac{n}{v}$, therefore $v = \frac{n}{C}$ $v = 0.0800 \text{ mol} / 0.300 \text{ mol} / \text{L}$ $= 0.267 \text{ L}$	$v = 0.0800 \cancel{\text{ mol}} \times \frac{1 \text{ L}}{0.300 \cancel{\text{ mol}}}$ $= 0.267 \text{ L}$

10. The mass can be found by multiplying the number of moles by the molar mass or you can use the formula $m = nM$.
11. The mass present can be calculated as follows:

List of Variables: $m = ?$ $n = 0.215 \text{ mol CaCl}_2$ $M = 110.98 \text{ g} / \text{mol}$	
Formula Method	Factor Label Method
$m = nM$ $= 0.215 \text{ mol} \times 110.98 \text{ g} / \text{mol}$ $= 23.9 \text{ g}$	$m = 0.215 \cancel{\text{ mol}} \times \frac{110.98 \text{ g}}{1 \cancel{\text{ mol}}}$ $= 23.9 \text{ g}$

12. a. The number of moles present can be calculated as follows:

List of Variables: $n = ?$ $m = 15.3 \text{ g}$ $M = 142.98 \text{ g/mol Ca(ClO)}_2$	
Formula Method	Factor Label Method
$n = \frac{m}{M}$ $= 15.3 \text{ g} / 142.98 \text{ g/mol}$ $= 0.107 \text{ mol}$	$n = 15.3 \cancel{\text{g}} \times \frac{1 \text{ mol}}{142.98 \cancel{\text{g}}}$ $= 0.107 \text{ mol}$

- b. The number of moles present can be calculated as follows:

List of Variables: $n = ?$ $m = 12.8 \text{ g}$ $M = 133.33 \text{ g/mol AlCl}_3$	
Formula Method	Factor Label Method
$n = \frac{m}{M}$ $= 12.8 \text{ g} / 133.33 \text{ g/mol}$ $= 0.0960 \text{ mol}$	$n = 12.8 \cancel{\text{g}} \times \frac{1 \text{ mol}}{133.33 \cancel{\text{g}}}$ $= 0.0960 \text{ mol}$

13. $m \longleftrightarrow n \longleftrightarrow C$



Knowing mass, you can determine volume as follows:

Finding the volume, starting from the mass, will take two steps: $m \rightarrow n$ and $n \rightarrow v$. If shown using units, the calculation would look something like the following:

$$m \rightarrow n \rightarrow v \quad v_L = \underset{\substack{\uparrow \\ 1 \\ \text{molar mass value}}}{\text{g}} \times \frac{1 \text{ mol}}{\text{g}} \times \frac{1 \text{ L}}{\underset{\substack{\uparrow \\ 1 \\ \text{concentration value}}}{\text{mol}}} = \text{L}$$

- 14.

List of Variables: $n = ?$ $v = 1.00 \text{ L}$ $C = 0.600 \text{ mol/L}$ $m = ?$ $M = 208.23 \text{ g/mol BaCl}_2$	
Formula Method	Factor Label Method
$C = \frac{n}{v}$, therefore $n = Cv$ $n = 0.600 \text{ mol/L} \times 1.00 \text{ L}$ $= 0.600 \text{ mol}$ $m = nM$ $= 0.600 \text{ mol} \times 208.23 \text{ g/mol}$ $= 125 \text{ g}$	$m = 1.00 \cancel{\text{L}} \times \frac{0.600 \text{ mol}}{\cancel{\text{L}}} \times \frac{208.23 \text{ g}}{1 \text{ mol}}$ $= 125 \text{ g}$

15. List of Variables: $n = ?$ $m = ?$
 $v = 0.0250 \text{ L (from 25.0 mL)}$ $M = 17.04 \text{ g/mol NH}_3$
 $C = 0.500 \text{ mol/L}$
- | Formula Method | Factor Label Method |
|---|---|
| $C = \frac{n}{v}$, therefore $n = Cv$
$n = 0.500 \text{ mol/L} \times 0.0250 \text{ L}$
$= 0.0125 \text{ mol}$
$m = nM$
$= 0.0125 \text{ mol} \times 17.04 \text{ g/mol}$
$= 0.213 \text{ g}$ | $m = 0.0250 \cancel{\text{L}} \times \frac{0.500 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{17.04 \text{ g}}{\cancel{\text{mol}}}$
$= 0.213 \text{ g}$ |
16. List of Variables: $n = ?$ $v = ?$
 $m = 15.6 \text{ g}$ $C = 0.100 \text{ mol/L}$
 $M = 261.35 \text{ g/mol Ba(NO}_3)_2$
- | Formula Method | Factor Label Method |
|---|--|
| $n = \frac{m}{M}$
$= 15.6 \text{ g} / 261.35 \text{ g/mol}$
$= 0.0597 \text{ mol}$
$v = \frac{n}{C}$
$= 0.0597 \text{ mol} / 0.100 \text{ mol/L}$
$= 0.597 \text{ L (Round answer after last calculation.)}$ | $v = 15.6 \cancel{\text{g}} \times \frac{1 \cancel{\text{mol}}}{261.35 \cancel{\text{g}}} \times \frac{1 \text{ L}}{0.100 \cancel{\text{mol}}}$
$= 0.597 \text{ L}$ |

Section 2: Activity 2

- You should use slightly less than half the final volume of water for dissolving the solid (solute).
- B** Dissolve the solid in half the volume you need to prepare.

D Fill the volumetric flask up to the calibration mark with distilled water.

E Stopper the volumetric flask and invert several times to mix.

A Measure the mass of the solid using a balance.

C Transfer the solution to an appropriate volumetric flask.
- The following is a sketch of a volumetric flask:



List of Variables: $n = ?$ $m = ?$ $v = 0.100 \text{ L (from 100 mL)}$ $M = 249.71 \text{ g/mol CuSO}_4 \cdot 5 \text{ H}_2\text{O}$ $C = 0.200 \text{ mol/L}$	
Formula Method	Factor Label Method
$n = Cv$ $= 0.200 \text{ mol/L} \times 0.100 \text{ L}$ $= 0.0200 \text{ mol}$ $m = nM$ $= 0.0200 \text{ mol} \times 249.71 \text{ g/mol}$ $= 4.99 \text{ g or } 5.0 \text{ g depending on the precision of the balance used}$	$m = 0.100 \cancel{\text{L}} \times \frac{0.200 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{249.71 \text{ g}}{\text{mol}}$ $= 4.99 \text{ g (or } 5.0 \text{ g)}$

Note that the molar mass of $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ includes the five water molecules. When this substance dissolves in water, though, since the water separates from the CuSO_4 , the solution is described as $\text{CuSO}_{4(\text{aq})}$.

- The solution is a transparent blue colour.
- Textbook question 36:

The prelab calculation may be done as follows:

List of Variables: $n = ?$ $m = ?$ $v = 2.00 \text{ L}$ $M = 165.87 \text{ g/mol CoCl}_2 \cdot 2 \text{ H}_2\text{O}$ $C = 0.0250 \text{ mol/L (from 25.0 mmol/L)}$	
Formula Method	Factor Label Method
$n = Cv$ $= 0.0250 \text{ mol/L} \times 2.00 \text{ L}$ $= 0.0500 \text{ mol}$ $m = nM$ $= 0.0500 \text{ mol} \times 165.87 \text{ g/mol}$ $= 8.29 \text{ g}$	$m = 2.00 \cancel{\text{L}} \times \frac{0.0250 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{165.87 \text{ g}}{\text{mol}}$ $= 8.29 \text{ g}$

The procedure for preparing this solution may be as follows:

- Measure 8.29 g of $\text{CoCl}_2 \cdot 2\text{H}_2\text{O}_{(s)}$ on a balance.
- Dissolve the solute in 1.00 L of water.
- Transfer the solution to a 2.00 L volumetric flask.
- Fill the flask to the calibration mark with water.
- Stopper the flask.
- Invert the flask several times in order to mix the solution thoroughly.

Textbook question 37:

The mass required may be calculated as follows:

List of Variables: $n = ?$ $m = ?$	
$v = 0.1000 \text{ L (from } 100.0 \text{ mL)}$ $M = 124.12 \text{ g/mol } (\text{NH}_4)_2 \text{OOCOO}$	
$C = 0.250 \text{ mol/L}$	
Formula Method	Factor Label Method
$n = Cv$ $= 0.250 \text{ mol/L} \times 0.1000 \text{ L}$ $= 0.0250 \text{ mol}$ $m = nM$ $= 0.0250 \text{ mol} \times 124.12 \text{ g/mol}$ $= 3.10 \text{ g}$	$m = 0.1000 \cancel{\text{L}} \times \frac{0.250 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{124.12 \text{ g}}{\text{mol}}$ $= 3.10 \text{ g}$

Textbook question 38:

The mass required may be calculated as follows:

List of Variables: $n = ?$ $m = ?$	
$v = 0.5000 \text{ L (from } 500.0 \text{ mL)}$ $M = 158.04 \text{ g/mol KMnO}_4$	
$C = 0.075 \text{ mol/L (from } 75 \text{ mmol/L)}$	
Formula Method	Factor Label Method
$n = Cv$ $= 0.075 \text{ mol/L} \times 0.5000 \text{ L}$ $= 0.0375 \text{ mol}$ $m = nM$ $= 0.0375 \times 158.04 \text{ g/mol}$ $= 5.9 \text{ g}$	$m = 0.5000 \cancel{\text{L}} \times \frac{0.075 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{158.04 \text{ g}}{\text{mol}}$ $= 5.9 \text{ g}$

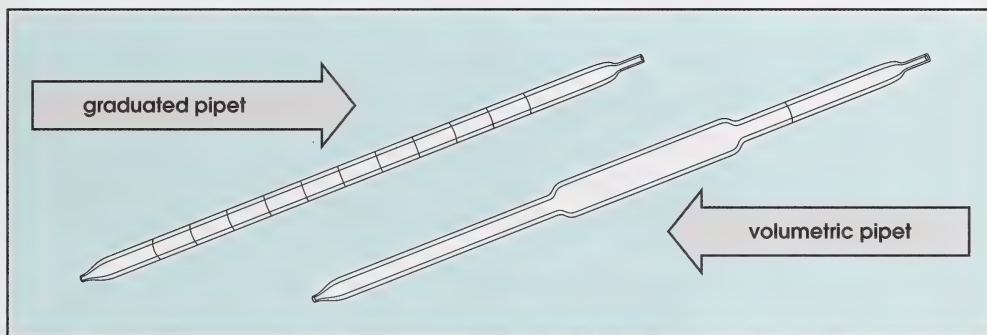
Textbook question 39:

The mass required may be calculated as follows:

List of Variables: $n = ?$ $m = ?$ $v = 0.500 \text{ L (from 500 mL)}$ $M = 40.00 \text{ g/mol NaOH}$ $C = 10.0 \text{ mol/L}$	
Formula Method	Factor Label Method
$n = Cv$ $= 10.0 \text{ mol/L} \times 0.500 \text{ L}$ $= 5.00 \text{ mol}$ $m = nM$ $= 5.00 \text{ mol} \times 40.00 \text{ g/mol}$ $= 200 \text{ g}$	$m = 0.500 \cancel{\text{L}} \times \frac{10.0 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{40.00 \text{ g}}{\cancel{\text{mol}}}$ $= 200 \text{ g}$

10. Dilution means "to water down."

11.



12. The two solutions are the same colour but the concentrated solution has a more intense colour than the dilute one.

13. The following calculation shows the number of moles pipetted:

$$n = Cv = 0.200 \text{ mol/L} \times 0.0100 \text{ L} = 0.00200 \text{ mol}$$

14. The moles of solute are the same amount – 0.00200 mol.

15. The concentration of the solute can be calculated as follows:

$$C = n/v = 0.00200 \text{ mol} / 0.100 \text{ L} = 0.0200 \text{ mol/L}$$

16. a. F c. T e. T g. F
 b. F d. T f. T

17. The relationship may be shown as follows: $v_i C_i = v_f C_f$

18.

Symbol	Description	Units
v_i	volume of concentrated solution to be diluted	L
C_i	molar concentration of concentrated solution	mol/L
v_f	volume of dilute solution to be prepared	L
C_f	molar concentration of dilute solution	mol/L

19. The final concentration may be calculated as follows: $C_f = \frac{v_i C_i}{v_f}$.

20. Textbook question 40:

The prelab calculation may be done as follows:

List of Variables: $v_i = ?$ $v_f = 2.00 \text{ L}$ $C_i = 5.00 \text{ mol/L H}_2\text{SO}_4$ $C_f = 0.500 \text{ mol/L}$	
Formula Method	Factor Label Method
$v_i C_i = v_f C_f$, therefore $v_i = \frac{v_f C_f}{C_i}$ $v_i = 2.00 \text{ L} \times \frac{0.500 \text{ mol/L}}{5.00 \text{ mol/L}}$ $= 0.200 \text{ L}$	$v_i = 2.00 \cancel{\text{L}} \times \frac{0.500 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{1 \text{ L}}{5.00 \cancel{\text{mol}}}$ $= 0.200 \text{ L}$ Note: For a concentrated solution, you must add the acid to the water.

The procedure for preparing this solution may be as follows:

Transfer 200 mL of the 5.00 mol/L sulphuric acid to 150 mL of water in a 2.00 L volumetric flask. Since this is a larger volume than the examples, you must use a graduated cylinder. Add distilled water to the solution until the calibration mark is reached. Stopper the flask. Invert the flask several times in order to mix the solution thoroughly.

Textbook question 41:

The volume that can be prepared may be calculated as follows:

List of Variables: $v_f = ?$ $v_i = 0.250 \text{ L (from 250 mL)}$ $C_f = 2.5 \text{ mol/L}$ $C_i = 15.4 \text{ mol/L HNO}_3$	
Formula Method	Factor Label Method
$v_i C_i = v_f C_f$, therefore $v_f = \frac{v_i C_i}{C_f}$ $v_f = 0.250 \text{ L} \times \frac{15.4 \text{ mol/L}}{2.5 \text{ mol/L}}$ $= 1.5 \text{ L}$	$v_f = 0.250 \cancel{\text{L}} \times \frac{15.4 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{1 \text{ L}}{2.5 \cancel{\text{mol}}}$ $= 1.5 \text{ L}$

Textbook question 42:

- a. The final concentration may be calculated as follows:

List of Variables: $C_f = ?$ $V_f = 0.1000 \text{ L}$ (from 100.0 mL)		$V_i = 0.00500 \text{ L}$ (from 5.00 mL) $C_i = 0.05000 \text{ mol/L CuSO}_4$
Formula Method		Factor Label Method
$V_i C_i = V_f C_f$, therefore $C_f = \frac{V_i C_i}{V_f}$ $C_f = 0.00500 \text{ L} \times \frac{0.05000 \text{ mol/L}}{0.1000 \text{ L}}$ $= 0.00250 \text{ mol/L}$		$C_f = 0.00500 \cancel{\text{L}} \times \frac{0.05000 \text{ mol}}{\cancel{\text{L}}} \times \frac{1}{0.1000 \text{ L}}$ $= 0.00250 \text{ mol/L}$

- b. The mass of solute present may be calculated as follows:

List of Variables: $n = ?$ $V = 0.0100 \text{ L}$ (from 10.0 mL) $C = 0.00250 \text{ mol/L}$		$m = ?$ $M = 159.61 \text{ g/mol CuSO}_4$
Formula Method		Factor Label Method
$n = Cv$ $= 0.00250 \text{ mol/L} \times 0.0100 \text{ L}$ $= 2.50 \times 10^{-5} \text{ mol}$ $m = nM$ $= 2.50 \times 10^{-5} \text{ mol} \times 159.61 \text{ g/mol}$ $= 0.00399 \text{ g}$		$m = \frac{0.00250 \cancel{\text{mol}}}{1 \cancel{\text{L}}} \times 0.0100 \cancel{\text{L}} \times \frac{159.61 \text{ g}}{1 \cancel{\text{mol}}}$ $= 0.00399 \text{ g}$

- c. The final dilute solution cannot be prepared directly from the solid. With the balance that is available, 0.00399 g cannot be measured accurately.

Section 2: Activity 3

1. The basic diet of most fish, plankton, is found in greater concentrations in the same regions as most pollution – along the shorelines of oceans. Therefore, it's easy for plankton to ingest the pollutants.
2. Since the basic organisms ingest the pollutants, the pollutants can be magnified through each of several steps in the food chain.
3. Dolphins have a fairly long lifespan – 20 to 50 y. Therefore, the effects of pollutants can be studied over a long term.

4. The results of the Pacific dolphin study may be outlined as follows:
 - The study involved 5000 samples of dolphin blubber.
 - Every sample contained PCBs.
 - The average PCB count in the samples was 10 ppm which is about 10 000 times higher than the sea in which they live.
5. The level of contaminants in the dolphins was 100 times higher than the level in the sardines.
6. Properties of PCBs and DDT that make them dangerous are as follows:
 - They spread rapidly and easily in the environment.
 - They don't dissolve readily.
 - They stay around a long time.
 - They don't burn easily.
7. The polar bear in the Arctic is showing signs of biomagnification. Polar bears feed on both fish and seals which contain contaminants ingested from lower in the food chain.
8. DDT or **dichlorodiphenyltrichloroethane** is an insecticide that has serious side effects. Animals can absorb it in their **fatty tissues**. This means that the chemical can **accumulate or collect** in the animal. DDT would be most concentrated in animals at the top of a **food chain**. When animals at the top of a food chain have a higher concentration of a substance than those animals lower down, **biomagnification** has happened. According to the chart on page 130, the concentration of DDT found in amphipods is **0.410 ppm** and the concentration of DDT in gulls is **99 ppm**. This table shows that even though the concentration of the pesticide in the lake is **0.000002 ppm**, it is **higher** in the living organisms.

Section 2: Activity 4

1. A concentrated solution is the one that has a high number of moles of solute per unit volume of solution.
2. A dilute solution is the one that has a low number of moles of solute per unit volume of solution.
3. The concentrated solutions are the hydrochloric acid and ammonia solutions.

The dilute solutions are the lead(II) nitrate solution and the copper(II) sulphate solution. Since some people might argue that 0.500 mol/L is not dilute, you might say that only the lead(II) nitrate solution is dilute.

4. Some possible answers may include the following:
 - spilling the chemical on yourself or on others
 - may cause dangerous reactions to happen
 - may be extremely reactive or unstable
5. Some possible hazards may include the following:
 - Solutions are highly poisonous if they get on your skin.
 - Disposing of the solutions may not be easy.

6. Some possible precautions may include the following:
 - Do not drink the solutions.
 - Use gloves.
 - Work in the fume hood.
 - Don't put solutions down the drain.
7.
 - a. The 6.0 mol/L bottle should have a WHMIS label if the bottle is to be stored.
 - b. The WHMIS label should outline the possible risks, the precautions necessary, and the first-aid required for the solution.
8.
 - a. Two-thirds of the mercury in the urine is caused by dental fillings.
 - b. Mercury vapour escapes by chewing, brushing your teeth, grinding your teeth, drilling by dentists, or by having the fillings break down due to their age.
 - c. According to the UN World Health Organization, **3 to 7 μg (micrograms)** of mercury is absorbed by people daily.
9. The Canadian Dental Health Association, the U.S. Food and Drug Administration, and the U.S. National Institute of Health have said that mercury dental fillings are safe.
10. The Universities of Arizona, Calgary, and Kentucky are researching the effects of mercury fillings.
11. The more fillings you have in your mouth, the greater the amount of mercury found in your body.
12.
 - a. The risks of removing and replacing your fillings may include the following:
 - The surgery of dental procedures may be dangerous.
 - Removing the fillings means more vapour escapes.
 - Removing the fillings may be painful.
 - All the mercury may not be removed.
 - Porcelain fillings need to be replaced more often.
 - b. Some benefits include the following:
 - The amount of mercury in your body is decreased.
 - Removing the fillings would give you peace of mind.
 - Porcelain fillings may look nicer.
 - c. Since there are five risks and three benefits of removing the fillings, you may decide that fillings are not worth removing. If you decide, however, that the benefits of removing the fillings are more important, you may decide that removing the fillings is worth it.
13. Your answer will depend on which decision you make, as described in part c. of the preceding question. If you can back up your decision by reasons such as the ones given in the preceding question, then your decision is a sound one.

Section 2: Follow-up Activities

Extra Help

1. To calculate the number of moles present in a solid you divide the **mass** by the **molar mass**. To find the number of moles of solute present in a solution you multiply the **volume** by the **concentration**.

2.

Solution	Molar Concentration	Volume of Solution	Moles of Solute	Mass of Dissolved Solute
ethanol solution	0.300 mol/L	25.0 mL	0.00750 mol	0.346 g
KI _(aq)	0.200 mol/L	175 mL	0.0350 mol	5.81 g
Na ₂ SO _{4(aq)}	0.0439 mol/L	1.50 L	0.0658 mol	9.35 g
CaCl _{2(aq)}	0.400 mol/L	2.00 L	0.800 mol	88.8 g

The following tables show the calculations for the preceding chart.

The calculations for determining the moles and mass of solute in the ethanol solution are as follows:

List of Variables: $n = ?$ $m = ?$ $v = 0.0250 \text{ L (from 25.0 mL)}$ $M = 46.08 \text{ g/mol}$ $C = 0.300 \text{ mol/L C}_2\text{H}_5\text{OH}$	
Formula Method	Factor Label Method
$n = Cv$ $= 0.300 \text{ mol/L} \times 0.0250 \text{ L}$ $= 0.00750 \text{ mol}$ $m = nM$ $= 0.00750 \text{ mol} \times 46.08 \text{ g/mol}$ $= 0.346 \text{ g}$	$m = 0.0250 \cancel{\text{L}} \times \frac{0.300 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{46.08 \text{ g}}{\text{mol}}$ $= 0.346 \text{ g}$ The first step ($\text{L} \times \frac{\text{mol}}{\text{L}}$) gives the moles required.

The calculations to determine the moles and mass of solute in KI_(aq) may be calculated as follows:

List of Variables: $n = ?$ $m = ?$ $v = 0.175 \text{ L (from 175 mL)}$ $M = 166.00 \text{ g/mol KI}$ $C = 0.200 \text{ mol/L}$	
Formula Method	Factor Label Method
$n = Cv$ $= 0.200 \text{ mol/L} \times 0.175 \text{ L}$ $= 0.0350 \text{ mol}$ $m = nM$ $= 0.0350 \text{ mol} \times 166.00 \text{ g/mol}$ $= 5.81 \text{ g}$	$m = 0.175 \cancel{\text{L}} \times \frac{0.200 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{166.00 \text{ g}}{\text{mol}}$ $= 5.81 \text{ g}$ The first step ($\text{L} \times \frac{\text{mol}}{\text{L}}$) gives the moles required.

The calculation for determining the moles and molar concentration of solute in $\text{Na}_2\text{SO}_{4(\text{aq})}$ are as follows:

List of Variables: $n = ?$ $C = ?$ $m = 9.35 \text{ g}$ $v = 1.50 \text{ L}$ $M = 142.04 \text{ g/mol Na}_2\text{SO}_4$	
Formula Method	Factor Label Method
$n = \frac{m}{M} = \frac{9.35 \text{ g}}{142.04 \text{ g/mol}}$ $= 0.0658 \text{ mol}$ $C = \frac{n}{v} = \frac{0.0658 \text{ mol}}{1.50 \text{ L}}$ $= 0.0439 \text{ mol/L}$	$C = 9.35 \text{ g} \times \frac{1 \text{ mol}}{142.04 \text{ g}} \times \frac{1}{1.50 \text{ L}}$ $= 0.0439 \text{ mol/L}$ The first step ($\text{g} \times \frac{\text{mol}}{\text{g}}$) gives the moles required.

The calculations for determining the molar concentration and mass of solute in $\text{CaCl}_{2(\text{aq})}$ are as follows:

List of Variables: $m = ?$ $C = ?$ $n = 0.800 \text{ mol}$ $v = 2.00 \text{ L}$ $M = 110.98 \text{ g/mol CaCl}_2$	
Formula Method	Factor Label Method
$C = \frac{n}{v}$ $= \frac{0.800 \text{ mol}}{2.00 \text{ L}}$ $= 0.400 \text{ mol/L}$ $m = nM$ $= 0.800 \text{ mol} \times 110.98 \text{ g/mol}$ $= 88.8 \text{ g}$	$C = 0.800 \text{ mol} \times \frac{1}{2.00 \text{ L}}$ $= 0.400 \text{ mol/L}$ $m = 0.800 \text{ mol} \times \frac{110.98 \text{ g}}{1 \text{ mol}}$ $= 88.8 \text{ g}$

3. a. ix f. viii
 b. ii g. iii
 c. iv h. x
 d. vii i. xi
 e. xii

4. The calculations for the procedures are as follows:

List of Variables: $v_i = ?$ $v_f = 2.00 \text{ L}$ $C_i = 14.8 \text{ mol/L NH}_3$ $C_f = 0.500 \text{ mol/L}$	
Formula Method	Factor Label Method
$v_i C_i = v_f C_f$, therefore $v_i = \frac{v_f C_f}{C_i}$ $v_i = 2.00 \text{ L} \times \frac{0.500 \text{ mol/L}}{14.8 \text{ mol/L}}$ $= 0.0676 \text{ L or } 67.6 \text{ mL}$	$v_i = 2.00 \cancel{\text{L}} \times \frac{0.500 \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{1 \text{ L}}{14.8 \cancel{\text{mol}}}$ $= 0.0676 \text{ L or } 67.6 \text{ mL}$

To prepare the 0.500 mol/L solution the technician uses a 2.00 L **volumetric flask**. She fills it half full of **water (distilled)** before she begins the dilution. Then she takes **67.6 (see calculation)** mL of the concentrated solution using a **graduated cylinder (pipette)**. She delivers this volume into the container and then adds enough **water (distilled)** to bring the level of the solution up to the mark. Then she **stoppers the volumetric flask and inverts it several times**.

Enrichment

1. The food chain you arrive at may look like the following:

algae and plankton → molluscs → seals → polar bear

The pollutants may come into the food chain at any level. For example, you might propose that the water is responsible for the pollution. The algae and plankton may be where the chemicals enter the food chain. Perhaps the chemical pollutants are created by industrial waste from the south. Because this industrial waste problem is not as severe in the north, the bears further north would have lower concentrations of pollutants.

2. Currently PCBs are used in electrical transformers. In the past, PCBs were used as hydraulic fluids, surface coatings for copy paper, sealants, caulking, resins, rubbers, paints, waxes, asphalts, and as capacitors in light bulbs and in electronics.

The PCBs entered the biosphere because they were not incinerated with other wastes. Many PCBs became airborne or were disposed of in landfills where the substances could leach into the groundwater. Some of the PCBs were accidentally spilled or were released because of leaking storage tanks. Oil recyclers processed oil containing PCBs and the oil was used to oil roads. PCBs then leached into the ground from the road.

3. Some questions you could ask of the retailers are the following:

- What protective clothing do you wear when you work with the chemicals?
- How do you load and unload the solutions from the processors?
- Is the building ventilated?
- What do you do in case of spills?
- Where do you dispose of the chemicals?
- Are the solutions pre-mixed?

Section 3: Activity 1

1. Some of the data on a periodic table includes the atomic mass, atomic number, boiling point, melting point, electronegativity, density, states of elements, and element symbols.

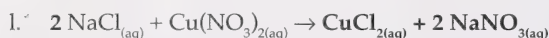
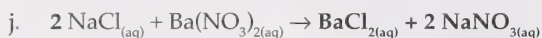
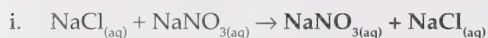
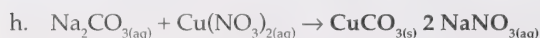
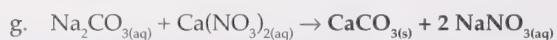
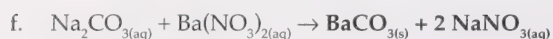
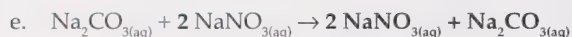
2. a. F b. T c. F d. T e. T f. T
3. A solid that forms when two solutions react is a precipitate.
4. The formulas all contain sodium ions. They are all sodium compounds.
5. The formulas all contain nitrate ions. They are all nitrate compounds.
6. Other sodium and nitrate compounds would likely be soluble as well.
7. a. No precipitate is formed when $\text{NaOH}_{(\text{aq})}$ and $\text{NaNO}_{3(\text{aq})}$ are mixed.
- b. The compounds $\text{Ba}(\text{NO}_3)_{2(\text{aq})}$, $\text{Ca}(\text{NO}_3)_{2(\text{aq})}$ and $\text{Cu}(\text{NO}_3)_{2(\text{aq})}$ formed a precipitate with $\text{NaOH}_{(\text{aq})}$.
8. a. $\text{NaOH}_{(\text{aq})} + \text{NaNO}_{3(\text{aq})} \rightarrow \text{NaNO}_{3(\text{aq})} + \text{NaOH}_{(\text{aq})}$
- b. $2 \text{NaOH}_{(\text{aq})} + \text{Ba}(\text{NO}_3)_{2(\text{aq})} \rightarrow \text{Ba}(\text{OH})_{2(\text{aq})} + 2 \text{NaNO}_{3(\text{aq})}$
- c. $2 \text{NaOH}_{(\text{aq})} + \text{Ca}(\text{NO}_3)_{2(\text{aq})} \rightarrow 2 \text{NaNO}_{3(\text{aq})} + \text{Ca}(\text{OH})_{2(\text{s})}$
- d. $2 \text{NaOH}_{(\text{aq})} + \text{Cu}(\text{NO}_3)_{2(\text{aq})} \rightarrow \text{Cu}(\text{OH})_{2(\text{s})} + 2 \text{NaNO}_{3(\text{aq})}$
9. $\text{NaNO}_{3(\text{aq})}$ is known to be soluble, therefore $\text{Cu}(\text{OH})_{2(\text{s})}$ must be the solid formed. This was the precipitate deduced by a process of elimination.
10. a. The precipitates formed were $\text{Ba}(\text{OH})_{2(\text{s})}$, $\text{Ca}(\text{OH})_{2(\text{s})}$ and $\text{Cu}(\text{OH})_{2(\text{s})}$. Most hydroxide compounds have low solubility, except for sodium hydroxide, since only one combination of four did not produce a precipitate.
- b. There was a precipitate formed when $\text{Ba}(\text{NO}_3)_{2(\text{aq})}$ reacted with $\text{NaOH}_{(\text{aq})}$. This was unexpected as the solubility table predicts $\text{Ba}(\text{OH})_{2(\text{s})}$ to be soluble. This probably means that $\text{Ba}(\text{OH})_{2(\text{s})}$ has borderline solubility.

11.

	NaOH	Na_3PO_4	Na_2CO_3	NaCl
NaNO_3	✗	✗	✗	✗
$\text{Ba}(\text{NO}_3)_2$	✓	✓	✓	✗
$\text{Ca}(\text{NO}_3)_2$	✓	✓	✓	✗
$\text{Cu}(\text{NO}_3)_2$	✓	✓	✓	✗

✓ – precipitate formed ✗ – no precipitate

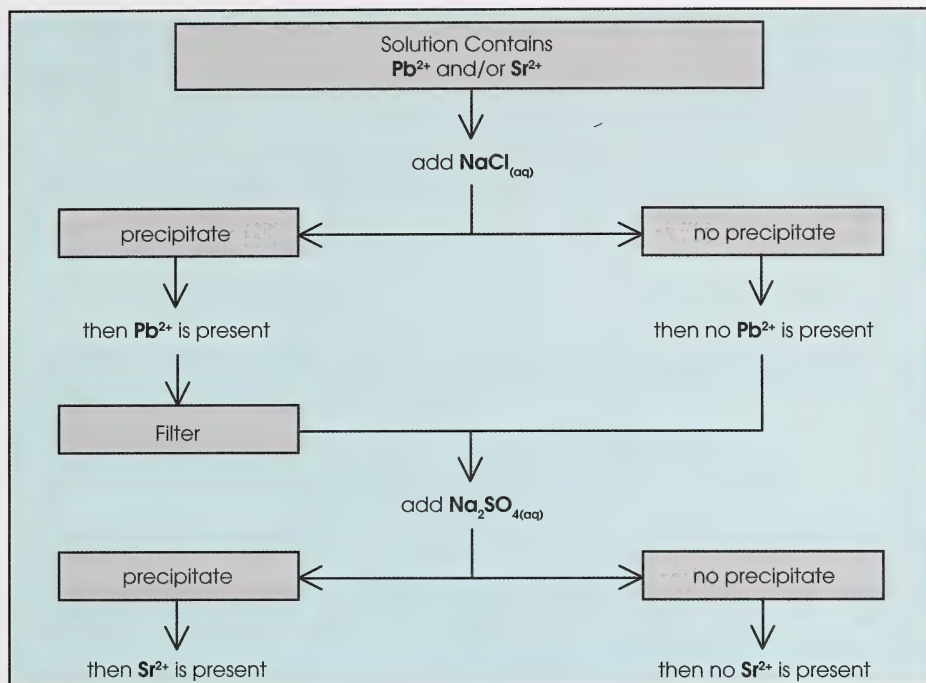
12. a. $\text{Na}_3\text{PO}_{4(\text{aq})} + \text{NaNO}_{3(\text{aq})} \rightarrow \text{NaNO}_{3(\text{aq})} + \text{Na}_3\text{PO}_{4(\text{aq})}$
- b. $2 \text{Na}_3\text{PO}_{4(\text{aq})} + 3 \text{Ba}(\text{NO}_3)_{2(\text{aq})} \rightarrow \text{Ba}_3(\text{PO}_4)_{2(\text{s})} + 6 \text{NaNO}_{3(\text{aq})}$
- c. $2 \text{Na}_3\text{PO}_{4(\text{aq})} + 3 \text{Ca}(\text{NO}_3)_{2(\text{aq})} \rightarrow \text{Ca}_3(\text{PO}_4)_{2(\text{s})} + 6 \text{NaNO}_{3(\text{aq})}$
- d. $2 \text{Na}_3\text{PO}_{4(\text{aq})} + 3 \text{Cu}(\text{NO}_3)_{2(\text{aq})} \rightarrow \text{Cu}_3(\text{PO}_4)_{2(\text{s})} + 6 \text{NaNO}_{3(\text{aq})}$



13. a. Barium, calcium, and copper(II) phosphate compounds have low solubility.
 b. Barium, calcium, and copper(II) carbonate compounds have low solubility.
 c. None of the chloride compounds in this lab has low solubility.
14. a. In this investigation, the compounds containing Na^+ , Cl^- , or NO_3^- were always soluble.
 b. Except for sodium hydroxide, sodium phosphate, and sodium carbonate, compounds containing hydroxide, phosphate, and carbonate ions had low solubility.
15. a. Calcium phosphates would not dissolve very easily in water because in this investigation they formed a precipitate.
 b. Sodium acetate would dissolve well in water because it is a sodium compound.
16. a. The soluble compounds are NaI and $\text{Al}(\text{NO}_3)_3$.
 b. The low solubility compounds are $\text{AgOH}_{(\text{s})}$, $\text{PbSO}_{4(\text{s})}$, and $\text{BaCO}_{3(\text{s})}$.
17. According to Figure 5.8 on page 122, when you test for the presence of an ion, another solution is added to **selectively precipitate** the ion from the solution. If two ions are present, then the solution you choose to react should **precipitate** one ion but not the other. If the precipitate happens in the first step, then you must **filter** it before you test for the presence of the other ion.

Ion Present	According to the Solubility Chart it has low solubility with . . .	Precipitates with an aqueous solution of . . .
Hg^+	Cl^- , Br^- , I^- , S^{2-} , OH^- , PO_4^{3-} , SO_3^{2-} , or CO_3^{2-}	sodium or potassium compounds like Na_2CO_3 or KCl
Br^-	Ag^+ , Pb^{2+} , Hg^+ , Cu^+ , or Ti^+	nitrate, chlorate, or perchlorate compounds like AgNO_3 or $\text{Pb}(\text{ClO})_2$
CO_3^{2-}	most ions	any solutions that do not contain Group 1 or ammonium ions, for example, calcium nitrate or magnesium sulphate

19.



20. a. The list of materials required includes the following:

- sample of unknown ions
- funnel
- test tubes
- test tube rack
- NaCl_(aq)
- stirring rod
- Na₂SO_{4(aq)}
- eye dropper

b. Steps in the procedure include the following:

- Pour half of the sample into a test tube.
- Add an equal volume of NaCl_(aq). If a precipitate forms keep adding more NaCl_(aq) drop by drop.
- If a precipitate has formed, filter out the solid and test the solution with an equal volume of Na₂SO_{4(aq)}.

c. Evidence may be entered in a chart as follows:

Solution Added	Precipitate Formed?
NaCl _(aq)	Yes
Na ₂ SO _{4(aq)}	Yes

21. A brief analysis of the findings may include the following:

Since sodium chloride formed a precipitate, this means that there are lead ions present. Chloride does not precipitate strontium ions. After the lead compound has been filtered, the sodium sulphate causes a precipitate to form because of the strontium ions. Therefore, the sample contained both Pb²⁺ and Sr²⁺ ions.

22.

Mixture	Possible Ions Present	Ions Present Have Low Solubility with . . .	Compound(s) that Selectively Precipitate Ions Present
1 example	Tl ⁺	Cl ⁻ , Br ⁻ , I ⁻ , S ²⁻ , CO₃²⁻ , PO₄³⁻ , SO₃²⁻	soluble compounds of Cl ⁻ , Br ⁻ , I ⁻ , S ²⁻ , e.g., NaCl, KBr
	Ra ²⁺	OH ⁻ , SO ₄ ²⁻ , CO₃²⁻ , PO₄³⁻ , SO₃²⁻	soluble compounds of OH ⁻ , SO ₄ ²⁻ , e.g., KOH, Na ₂ SO ₄
2	SO ₄ ²⁻	Ag⁺ , Pb²⁺ , Ca ²⁺ , Ra ²⁺ , Ba ²⁺ , Sr ²⁺	soluble compounds of Ca ²⁺ , Ra ²⁺ , Ba ²⁺ , Sr ²⁺ , e.g., Ca(NO ₃) ₂ , Ba(CH ₃ COO) ₂
	Cl ⁻	Ag⁺ , Hg ⁺ , Pb²⁺ , Cu ⁺ , Tl ⁺	soluble compounds of Cu ⁺ , Tl ⁺ , e.g., TlCH ₃ COO, CuCH ₃ COO
3	CH ₃ COO ⁻	Ag⁺	precipitate of Cl ⁻ filtered first – then soluble compounds of Ag ⁺ , added, e.g., AgNO ₃
	Cl ⁻	Ag⁺ , Hg ⁺ , Pb ²⁺ , Cu ⁺ , Tl ⁺	soluble compounds of Hg ⁺ , Pb ²⁺ , Cu ⁺ , Tl ⁺ e.g., HgNO ₃ , Pb(NO ₃) ₂ , CuCH ₃ COO, TlNO ₃

23. Textbook question 10:

Any Group 2 ion will selectively precipitate carbonate ions but not sulphide ions since Group 2 ions are soluble with S²⁻ but not with CO₃²⁻. Therefore any solutions containing Be²⁺, Mg²⁺, Ca²⁺, Sr²⁺, Ba²⁺, or Ra²⁺ will selectively precipitate the carbonate ions.

24. Textbook question 19:

If you wish to selectively precipitate the ions, then you could pick any metal ion not in Group 1 or Group 2, and not NH₄⁺, Ag⁺, Hg⁺, Cu⁺, Tl⁺, or Pb²⁺ to precipitate S²⁻ first. For example, you could use Fe³⁺. Any other ion that has low solubility with chloride ions, like Ag⁺, can be used for the chloride after the first precipitate is filtered.

25. You could precipitate Ag⁺ ions by adding sodium chloride solution and filtering the solution of the silver chloride before disposing of it.
26. You could precipitate the Pb²⁺ ions by adding sodium chloride solution and filtering the solution of the lead(II) chloride before disposing of it.
27. An analysis of the findings may include the following:

Solution A contains Ba²⁺ since it forms a precipitate with the sulphate ions. The flame test confirms this because it produces a yellowish-green flame.

Solution B contains Cu²⁺ because the colour of solution is blue and the flame test produces a green colour. The solubility chart shows the Cu²⁺ is soluble with sulphate.

Solution C contains lithium because the flame test is red. Lithium (a Group 1 ion) is also soluble with sulphate according to the solubility chart.

Solution D contains Ag⁺. It shows no colour in the flame test so this distinguishes it from Ba²⁺. Silver ions form a precipitate like barium ions do.

28. By observing the colours of the solutions, $K_2Cr_2O_7$ can be immediately identified because it will be orange. The other two solutions will need to be identified using precipitation. Ca^{2+} , Sr^{2+} , Ba^{2+} or Ra^{2+} will selectively precipitate the sulphate solution. The remaining solution must then be $NaCl_{(aq)}$.

Section 3: Activity 2

1. Ionic compounds and acids are electrolytes.
2. Ions are responsible for the conductivity of a solution.
3. The evidence may be shown as follows:

Solution	Degree of Conductivity
$CH_3COOH_{(aq)}$	poor – bulb barely lit up
$HCl_{(aq)}$	very good – bulb lit up brightly and flashed

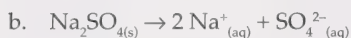
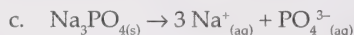
4. Hydrochloric acid is the strongest electrolyte – the light bulb was brighter with this solution.
5. There are more ions present in the hydrochloric acid solution than in the acetic acid solution, which creates greater conductivity.
6. The process that acidic compounds undergo when they dissolve to form conducting solutions is **ionization**.
7. Calcium chloride, $CaCl_2$, dissociates to give more ions (3 mol of ions/mol of $CaCl_2$) than $NaCl$ (2 mol of ions/mol of $NaCl$) – and therefore gives a greater conductivity in solution. Calcium chloride is used in preference to sodium chloride as road salt in winter. Calcium chloride's greater concentration of ions makes it more effective in keeping water from freezing on the roads.
8. The overall or net charge is zero.

Solute	Solubility	Dissociation Equation
$HClO_4$	soluble	$HClO_{4(l)} \rightarrow H^+_{(aq)} + ClO^-_{4(aq)}$
K_2SO_4	soluble	$K_2SO_{4(s)} \rightarrow 2 K^+_{(aq)} + SO^{2-}_{4(aq)}$
$Ca_3(PO_4)_2$	low solubility	
$NaBr$	soluble	$NaBr_{(s)} \rightarrow Na^+_{(aq)} + Br^-_{(aq)}$
$Pb(NO_3)_2$	soluble	$Pb(NO_3)_{2(s)} \rightarrow Pb^{2+}_{(aq)} + 2 NO^-_{3(aq)}$
$BaSO_4$	low solubility	
$MgCl_2$	soluble	$MgCl_{2(s)} \rightarrow Mg^{2+}_{(aq)} + 2 Cl^-_{(aq)}$

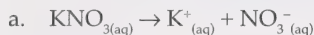
10. The concentration of the dollar coin is **one** particle per bank. The dollar coin can be changed into a total of **three** particles. The concentration of the 50¢ coin is **one** particle per bank and the concentration of the quarters is **two** particles per bank.

11. The concentration of the barium chloride solution is **1 mol/L**. After the formula unit dissociates, the concentration of $\text{Ba}^{2+}_{(\text{aq})}$ is **1 mol/L** and the concentration of $\text{Cl}^{-}_{(\text{aq})}$ is **2 mol/L**. You can compare the \$1 coin in the bank example to the **formula unit for barium chloride** in the solution example. Changing the \$1 coin can be compared to **dissociating** the barium chloride. In the bank example, there were **three** coins produced. In the solution example there were **3 moles** of ions formed.

12. **Textbook question 21:**

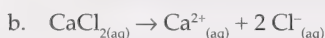


Textbook question 22:



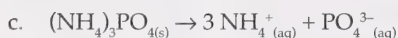
$$[\text{K}^{+}_{(\text{aq})}] = 1 \times 0.14 \text{ mol/L} = 0.14 \text{ mol/L}$$

$$[\text{NO}_3^{-}_{(\text{aq})}] = 1 \times 0.14 \text{ mol/L} = 0.14 \text{ mol/L}$$



$$[\text{Ca}^{2+}_{(\text{aq})}] = 1 \times 0.14 \text{ mol/L} = 0.14 \text{ mol/L}$$

$$[\text{Cl}^{-}_{(\text{aq})}] = 2 \times 0.14 \text{ mol/L} = 0.28 \text{ mol/L}$$



$$[\text{NH}_4^{+}_{(\text{aq})}] = 3 \times 0.14 \text{ mol/L} = 0.42 \text{ mol/L}$$

$$[\text{PO}_4^{3-}_{(\text{aq})}] = 1 \times 0.14 \text{ mol/L} = 0.14 \text{ mol/L}$$

13. Calculations may be made as follows:

List of Variables: $C = ?$ $n = 0.371 \text{ mol Na}_3\text{PO}_4$ $v = 0.250 \text{ L (from 250 mL)}$	
Formula Method	Factor Label Method
$C = \frac{n}{v}$ $= \frac{0.371 \text{ mol}}{0.250 \text{ L}}$ $= 1.484 \text{ mol/L Na}_3\text{PO}_4$	$C = 0.371 \text{ mol} \times \frac{1}{0.250 \text{ L}}$ $= 1.484 \text{ mol/L}$

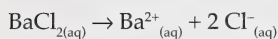


$$[\text{Na}^{+}_{(\text{aq})}] = 3 \times 1.484 \text{ mol/L} = 4.45 \text{ mol/L} \text{ The concentration of cations is } 4.45 \text{ mol/L.}$$

$$[\text{PO}_4^{3-}_{(\text{aq})}] = 1 \times 1.484 \text{ mol/L} = 1.48 \text{ mol/L} \text{ The concentration of anions is } 1.48 \text{ mol/L.}$$

14. Calculations may be made as follows:

List of Variables: $n = ?$ $C = ?$	
$m = 2.08 \text{ g}$ $v = 0.100 \text{ L (from 100 mL)}$	
$M = 208.23 \text{ g/mol BaCl}_2$	
Formula Method	Factor Label Method
$n = \frac{m}{M}$ $= \frac{2.08 \text{ g}}{208.23 \text{ g/mol}}$ $= 0.00999 \text{ mol}$ $C = \frac{n}{v}$ $= \frac{0.00999 \text{ mol}}{0.100 \text{ L}}$ $= 0.0999 \text{ mol/L BaCl}_2$	$C = 2.08 \cancel{\text{g}} \times \frac{1 \text{ mol}}{208.23 \cancel{\text{g}}} \times \frac{1}{0.100 \text{ L}}$ $= 0.0999 \text{ mol/L}$



$[\text{Ba}^{2+}_{(\text{aq})}] = 1 \times 0.0999 \text{ mol/L} = 0.0999 \text{ mol/L}$ The concentration of cations is 0.0999 mol/L.

$[\text{Cl}^{-}_{(\text{aq})}] = 2 \times 0.0999 \text{ mol/L} = 0.200 \text{ mol/L}$ The concentration of anions is 0.200 mol/L.

15. Calculations may be made as follows:

List of Variables: $n = ?$ $C = ?$	
$m = 5.50 \text{ g}$ $v = 2.50 \text{ L}$	
$M = 294.20 \text{ g/mol K}_2\text{Cr}_2\text{O}_7$	
Formula Method	Factor Label Method
$n = \frac{m}{M}$ $= \frac{5.50 \text{ g}}{294.20 \text{ g/mol}}$ $= 0.0187 \text{ mol}$ $C = \frac{n}{v}$ $= \frac{0.0187 \text{ mol}}{2.50 \text{ L}}$ $= 0.00748 \text{ mol/L}$	$C = 5.50 \cancel{\text{g}} \times \frac{1 \text{ mol}}{294.20 \cancel{\text{g}}} \times \frac{1}{2.50 \text{ L}}$ $= 0.00748 \text{ mol/L}$



$[\text{Cr}_2\text{O}_7^{2-}_{(\text{aq})}] = 1 \times 0.00748 \text{ mol/L} = 0.00748 \text{ mol/L}$ The $[\text{Cr}_2\text{O}_7^{2-}_{(\text{aq})}]$ is 0.00748 mol/L.

Section 3: Activity 3

- The clown juggling the balls is a system at equilibrium. The system is a **closed** system since there are no balls entering or leaving. There is a **balance** since the two opposing forces happen at the same **rate**. One force is the ball being thrown by the clown, the other is the ball being caught by the clown. Because these two processes are **opposite** and happen at the same speed, an **equilibrium** exists. It is a **dynamic** equilibrium because the balls are always in **motion**. The juggling of the balls is analogous to what happens in a **saturated** solution. If the ball leaving the clown's hand is compared to the dissolving of a solute, then the clown catching the ball is like **crystallization**. There is a dynamic equilibrium that exists in a saturated solution since the rate of **dissolving** is equal to the rate of crystallizing. When you observe the solution, you see no **overall** change.
- One test of **dynamic equilibrium** is to shake a jar of **saturated solution or pickling salt solution** every day for two weeks. The amount of solute is **constant (same)** but the shapes of the particles change. This shows that the rates of **dissolving** and **crystallizing** are equal. A second test involves the addition of radioactive iodine **crystals** and a saturated solution to test tubes containing a saturated solution. The radioactive iodine is **spread** throughout the mixture. It is found in the crystals and in the solution. This shows that the **rates** of dissolving and crystallizing are **equal**. It also shows that these two **processes** happen all the time.

Solute	Electrolyte?	Equilibrium Equation
Limestone, $\text{CaCO}_{3(s)}$	yes	$\text{CaCO}_{3(s)} \rightleftharpoons \text{Ca}^{2+}_{(aq)} + \text{CO}_3^{2-}_{(aq)}$
Sugar, $\text{C}_{12}\text{H}_{22}\text{O}_{11(s)}$	no	$\text{C}_{12}\text{H}_{22}\text{O}_{11(s)} \rightleftharpoons \text{C}_{12}\text{H}_{22}\text{O}_{11(aq)}$
$\text{Na}_3\text{PO}_{4(s)}$	yes	$\text{Na}_3\text{PO}_{4(s)} \rightleftharpoons 3 \text{Na}^{+}_{(aq)} + \text{PO}_4^{3-}_{(aq)}$
$\text{CuSO}_{4(s)}$	yes	$\text{CuSO}_{4(s)} \rightleftharpoons \text{Cu}^{2+}_{(aq)} + \text{SO}_4^{2-}_{(aq)}$
$\text{CO}_{2(g)}$	no	$\text{CO}_{2(g)} \rightleftharpoons \text{CO}_{2(aq)}$

Section 3: Follow-up Activities

Extra Help

- Yes, $\text{Ag}_2\text{S}_{(s)}$ precipitates.
 - no precipitate
 - Yes, $\text{SrSO}_{4(s)}$ precipitates.
 - Yes, $\text{TlCl}_{(s)}$ precipitates.
 - no precipitate
- $\text{Pb}(\text{NO}_3)_{2(aq)} + 2 \text{NaCl}_{(aq)} \rightarrow \text{PbCl}_{2(s)} + 2 \text{NaNO}_{3(aq)}$
 - $\text{Ca}(\text{NO}_3)_{2(aq)} + \text{Na}_2\text{SO}_{4(aq)} \rightarrow \text{CaSO}_{4(s)} + 2 \text{NaNO}_{3(aq)}$

Solute	Solubility	Dissociation Equation
$\text{Cu}(\text{NO}_3)_2$	soluble	$\text{Cu}(\text{NO}_3)_{2(s)} \rightarrow \text{Cu}^{2+}_{(aq)} + 2 \text{NO}_3^{-}_{(aq)}$
PbSO_4	low solubility	
$\text{Ba}(\text{OH})_2$	soluble	$\text{Ba}(\text{OH})_{2(s)} \rightarrow \text{Ba}^{2+}_{(aq)} + 2 \text{OH}^{-}_{(aq)}$
$\text{K}_2\text{Cr}_2\text{O}_7$	soluble	$\text{K}_2\text{Cr}_2\text{O}_{7(s)} \rightarrow 2 \text{K}^{+}_{(aq)} + \text{Cr}_2\text{O}_7^{2-}_{(aq)}$

4. a. $\text{Na}_2\text{S}_{(\text{aq})}$ – Use any metal ion (e.g., iron(III) or silver ions) except Group 1, Group 2, or NH_4^+ .
- b. $\text{CuSO}_{4(\text{aq})}$ – To precipitate the copper(II) ions you could use a sulphide, hydroxide, carbonate, phosphate, or sulphite compound; to precipitate the sulphate ions you could use a silver, lead(II), calcium, barium, strontium, or radium compound.
- c. $\text{SrBr}_{2(\text{aq})}$ – To precipitate the strontium ions you could use sulphate, sulphide, hydroxide, phosphate, sulphite, or carbonate compounds; to precipitate the bromide ions you could use silver ions, lead(II) ions, mercury ions, copper(I) ions, or thallium(I) ions.
- d. $\text{KI}_{(\text{aq})}$ – To precipitate the iodide ions you could use silver ions, lead(II) ions, mercury ions, copper(I) ions, or thallium(I) ions.

5.

Solute Concentration	Solute	[cations] (mol/L)	[anions] (mol/L)
3.0 mol/L	$\text{NaCl}_{(\text{aq})}$	$[\text{Na}^+] = 3.0$	$[\text{Cl}^-] = 3.0$
6.0 mol/L	$\text{HCl}_{(\text{aq})}$	$[\text{H}^+] = 6.0$	$[\text{Cl}^-] = 6.0$
0.100 mol/L	$\text{Pb}(\text{NO}_3)_{2(\text{aq})}$	$[\text{Pb}^{2+}] = 0.100$	$[\text{NO}_3^-] = 0.200$
0.500 mol/L	$\text{Na}_3\text{PO}_{4(\text{aq})}$	$[\text{Na}^+] = 1.500$	$[\text{PO}_4^{3-}] = 0.500$

6. a. You would notice nothing happening in the beaker because the saturated solution is in equilibrium.
- b. After 24 h, there would still be dissolving happening.
- c. Crystallizing is occurring since the saturated solution is in dynamic equilibrium.
- d. $\text{Na}_3\text{PO}_{4(\text{s})} \rightleftharpoons 3 \text{Na}^+_{(\text{aq})} + \text{PO}_4^{3-}_{(\text{aq})}$

e.

List of Variables: $n = ?$ $m = 20 \text{ g}$ $M = 163.94 \text{ g/mol Na}_3\text{PO}_4$		$C = ?$ $v = 0.0500 \text{ L (from 50.0 mL)}$
Formula Method	Factor Label Method	
$n = \frac{m}{M} = \frac{20 \text{ g}}{163.94 \text{ g/mol}}$ $= 0.12 \text{ mol}$ $C = \frac{n}{v} = \frac{0.12 \text{ mol}}{0.0500 \text{ L}}$ $= 2.4 \text{ mol/L Na}_3\text{PO}_4$	$C = 20 \cancel{\text{g}} \times \frac{1 \text{ mol}}{163.94 \cancel{\text{g}}} \times \frac{1}{0.0500 \text{ L}}$ $= 2.4 \text{ mol/L}$	

$$[\text{Na}^+_{(\text{aq})}] = 3 \times 2.4 \text{ mol/L}$$

$$= 7.3 \text{ mol/L} \quad \text{The concentration of cations is 7.3 mol/L.}$$

$$[\text{PO}_4^{3-}_{(\text{aq})}] = 1 \times 2.4 \text{ mol/L}$$

$$= 2.4 \text{ mol/L} \quad \text{The concentration of anions is 2.4 mol/L.}$$

Remember, final answers are based on unrounded intermediate values.

Enrichment

1. a. After you drop in the crystals, a crystal growth begins to form and grow up like branches on a tree through the liquid. The growths bend and branch and different crystals cause different colours. FeCl_3 forms a brown crystal. CuCl_2 is a bright green. $\text{Co}(\text{NO}_3)_2$ is a dark blue. ZnSO_4 is white.
 - b. The compounds form the solids because they dissolve and the ions precipitate the thiosulphate ions in solution.
 - c. Any compound that is completely soluble according to the solubility table should have no effect. Combinations of Group 1 and ammonium ions with nitrate and acetate ions will have no effect.
2. Rainwater containing dissolved $\text{CO}_{2(\text{g})}$ enters the earth which contains limestone ($\text{CaCO}_{3(\text{s})}$). The limestone reacts with the water and $\text{CO}_{2(\text{g})}$ to form calcium hydrogen carbonate. This is the compound that has low solubility. The reaction that happens is the following: $\text{CO}_{2(\text{g})} + \text{H}_2\text{O}_{(\text{l})} + \text{CaCO}_{3(\text{s})} \rightarrow \text{Ca}(\text{HCO}_3)_{2(\text{aq})}$

The water in a cave is saturated with $\text{Ca}(\text{HCO}_3)_{2(\text{aq})}$. It drips off the roof of a cave. Because the water is evaporating, the calcium hydrogen carbonate increases in concentration to the point of saturation, then precipitates.

The equilibrium that is affected is as follows: $\text{Ca}(\text{HCO}_3)_{2(\text{s})} \rightleftharpoons \text{Ca}^{2+}_{(\text{aq})} + 2 \text{HCO}_3^{-}_{(\text{aq})}$

The stalactites (mineral icicles down from the roof) are caused by the continuous dripping and evaporating. The stalagmites (mineral icicles rising from the floor) are caused by the drops hitting the floor.

Scale is produced in the same manner. Hard water contains compounds such as calcium or magnesium hydrogen carbonate. These compounds have low solubilities. In humidifiers or tea kettles the water evaporates quickly and the compounds increase in concentration, and then precipitate.

3. a. The following is a data table based on a "hard" water sample.

The Number of Drops Needed to Produce a Lather for 30 s

Sample (50 mL)	Number of Drops of Soap
Rainwater	3
Drinking water	25
Boiled water	16

- b. An analysis of the water samples may be as follows:

The rainwater is the control in this experiment. It contains no minerals so it is soft water. It takes three drops to produce a lather that lasts for 30 seconds. The unboiled drinking water is hard water. It takes the greatest number of drops to get it to lather for 30 seconds. The boiled water sample still shows some hardness because it took 16 drops of soap to produce a lasting lather. It is softer than the drinking water because boiling removes some of the mineral ions. Since there is still some hardness remaining, this means that either boiling cannot remove all the hardness or the water was not boiled for long enough.

Note: In some cases where hydrogen carbonate is the only compound producing hardness, the boiled water may have the same results as the rainwater.

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